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EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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See Advertisement page 28. 6462

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See Advertisement page 48, April 12. 2402

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See Full Page Advt. page 70, April 5.

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Messrs. FULLER, HORSEY, SONS & CASSELL beg to announce that

Tenders for the Purchase of

the EQUIPPED ENGINEERING WORKS at Croydon will be received at their offices up to Twelve noon, on MONDAY next, APRIL 22nd, instead of by the date previously advertised.
The tenants' fixtures, consisting mainly of HIGH-CLASS MACHINE TOOLS, are included in the sale, of which possession will be given on completion. The ground rent of the premises is £200 per annum and the unexpired term of 14 years, but the purchaser can determine the lease in 1921 or 1925, or should he desire permanent occupation, the freehold would be sold.
The purchaser will be at liberty, should he prefer to do so, to remove all, or any, of the machines to other works, after the 24th June next.
Further particulars may be had of Messrs. FULLER, HORSEY & Co., Mechanical Auctioneers and Valuers, 133, High Holborn, W.C. 1. L 29

By Order of the Proprietor, who is retiring from business, Messrs. FULLER, HORSEY, SONS & CASSELL are instructed to invite

Tenders for the Purchase,

in one lot, as a GOING CONCERN, of the old-established FREEHOLD SHIPBUILDING & ENGINEERING WORKS at Canning Town of A. W. ROBERTSON & CO.
The works, which have the extensive frontage to Bow Creek of 480 ft., contain an area of nearly two acres. The buildings are conveniently arranged for economical construction and are equipped with modern Shipbuilding and Engineering Plant.
The whole of the fixed plant, machinery and fixtures, as also the GOODWILL OF THE BUSINESS, with patterns and drawings and work in progress, will be included in the sale. The purchaser will have an option of acquiring the loose plant, tools, stock and stores at a valuation. He will be entitled to the beneficial interest in the running contracts, but required to give an indemnity in respect thereof.
Tenders, which must be on the form attached to the particulars, must be delivered by Twelve noon on WEDNESDAY, MAY 1st, at the Office of the AUCTIONEERS, 133, High Holborn, W.C.1.
The Works may be viewed by orders only, to be obtained of Messrs. FORBES & SON, Solicitors, 19, Mark Lane, E.C., and of Messrs. FULLER, HORSEY & CO., Mechanical Auctioneers and Valuers, 133, High Holborn, W.C. 1. K 942

THE LIGHTING COMMITTEE OF THE ISLINGTON BOROUGH COUNCIL invite

Tenders for the Supply and

ERECTION of MACHINERY and PLANT, viz.:—
(a) 5000 Kw. Steam Turbine, Alternator, Exciter, Condensing Plant, Switch-Gear, Piping, &c.
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Specification, General Conditions, and Form of Tender may be obtained on application to the ELECTRICAL ENGINEER, 50, Eden Grove, Holloway, N. 7, on or after the 29th April, 1918. A deposit of £2/2/- will be required, which will be returned on receipt of a bona fide tender.
Tenders, under seal and endorsed on the outside "Tender for Electric Lighting Plant," to be addressed to the undersigned and delivered at the Town Hall, Upper Street, Islington, N. 1, not later than Noon, Friday, the 24th May, 1918.
By order,
C. G. B. FLETCHER, Town Clerk.
Town Hall, Upper Street, N. 1.
12th April, 1918. L 71

RICHMOND MAIN SEWERAGE BOARD.
CONTRACTS FOR STORES.

The Board are prepared to receive

Tenders for the Supply and

DELIVERY to their Works during the year ending May 31st, 1919, of the following STORES:—
Steam Coal.
House Coal.
Grey Lime.
Brixton Lime.
Sewage Precipitants.
Jute Press Cloth.
Specifications and particulars may be inspected from 10 a.m. to 4 p.m., at the office of Mr. WILLIAM FAIRLEY, M.Inst.C.E., Engineer to the Board, West Hall Road, Kew Gardens, where also forms of Tender may be obtained.
Sealed Tenders, on the forms provided, to be delivered to the undersigned on or before TUESDAY, May 7th, 1918.
Security for the due fulfilment of the Contracts will be required in accordance with the provisions of the Public Health Act, 1875.
The Board do not bind themselves to accept the lowest or any Tender.
J. LESLIE G. POWELL, Clerk to the Board.
The Sessions House, Richmond, Surrey.
10th April, 1918. L 153

APPOINTMENTS OPEN.

BRISTOL EDUCATION COMMITTEE.

TEMPLE JUNIOR TECHNICAL SCHOOL (ENGINEERING).

Wanted, Immediately, for

the above-named School, a TEACHER of ENGINEERING SUBJECTS, including Metal-work and Machine Drawing. Ability to teach Science a recommendation. Preference given to a practical engineer with teaching experience. Candidates should be prepared to interest themselves in School Games and Physical Exercises with the boys.
Salary £180 per annum, rising by annual increments of £10 to £200 per annum.
Forms of application, which should be received not later than Thursday, 25th April, may be obtained by sending a stamped, addressed foolscap envelope to the undersigned.
WM. AVERY ADAMS, Secretary for Education.
Guildhall, Bristol, 9th April, 1918. L 27

DARLINGTON EDUCATION COMMITTEE.

TECHNICAL COLLEGE.

Wanted, as Soon as Possible,

INSTRUCTOR capable of lecturing on Elementary Electrical Engineering and giving practical instruction in the Laboratory and Wiring Workshop. Salary at least £4 per week. Full particulars as to duties and Forms of Application may be obtained from the undersigned.
A. C. BOYDE, Secretary.
Education Office, Darlington. April, 1918. L 21

CITY OF LIVERPOOL.

EDUCATION COMMITTEE.

The following Teachers (In-

eligible for Military service) are REQUIRED for Junior Technical Schools in Liverpool:—
(1) A Teacher (man or woman) of ENGLISH SUBJECTS and MATHEMATICS, preferably with an Arts Degree.
(2) A Teacher (man or woman) of MATHEMATICS, PHYSICS and CHEMISTRY, preferably with a Science Degree.
(3) A Teacher of WOODWORKING, with special knowledge of the Building Trades, with teaching experience.
(4) A Teacher of METAL WORKING, with special knowledge of Engineering Trades.
Applications are invited from qualified men who have served in the Army or Navy and have received their discharge.
Salaries from £160 to £200 (man), £125 to £150 (woman) per annum, according to qualifications and experience.
Applications, giving particulars of age, education, Workshop and Teaching experience, with copies of testimonials and names of references, to be sent not later than Saturday, 27th April, 1918, to the DIRECTOR OF EDUCATION, Education Offices, Sir Thomas Street, Liverpool, from whom forms of application and further particulars as to the appointment may be obtained.
E. R. PICKMERE, Town Clerk. L 64

Wanted in Government Office

(London), Civil Engineering Drawing Office ASSISTANTS. Salaries from £3 to £6 per week and overtime. Applicants must be ineligible for general Military service and should give particulars of experience and age, with references or copy of any testimonials, to BOX 1235, WILLING'S 126, Strand, London, W.C. 2. L 153

Wanted, Steel Works Chemist

for steel foundry with electric furnace. No one at present on Government work will be engaged.—Apply at your nearest EMPLOYMENT EXCHANGE, mentioning No. A 4973. L 17

Power Station Chemist

WANTED, with experience, on large plant, in testing water, coal, oil, and flue gases. State age, medical category, and particulars of most recent similar work. Wages 45s., plus 20s. war bonus and 13½ per cent.—Address, L 140, Offices of ENGINEERING.

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Wanted, Assistant for

Drawing Office of Government Department, Portland district. Male applicants must be ineligible for Military service and not engaged on other Government work.—Address, stating age, salary required, experience and references, BOX 1209, WILLINGS, 126, Strand, London, W.C. 2. L 115

Works Manager Wanted, for

large Engineering Works; one having experience in Heavy Machine Tools preferred.—Address, giving full particulars as to previous experience, salary desired and copies of references, L 84, Offices of ENGINEERING.

Shipyard Manager for

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Foundry, experienced and energetic FOUNDRY MANAGER with thorough knowledge of the production of light castings by modern methods. No one already on Government work will be engaged.—Address, stating age, experience and salary required, L 62, Offices of ENGINEERING.

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First-class man to take charge of Iron and Bronze Foundries, must have thorough practical and technical knowledge of all branches of Foundry work. Must also have first-class experience of latest machine moulding methods. Present output 70/75 tons per week.—Apply, stating age, experience and salary required, to ALFRED HERBERT, LTD., Machine Tool Makers, Edgwick Works, Coventry. K 963

AIRCRAFT WORKS, LONDON.

PURCHASING DEPARTMENT.

Applications are Invited for

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Applicants must have had wide commercial experience in the purchase of engineer's materials and tools, and in sub-contract work.
Full details must be sent of experience and previous positions held. Age and salary required must be stated. All such details will be treated in strict confidence.
No one will be engaged who is on Government work or resident more than 10 miles away.
Address, K 957, Offices of ENGINEERING.

Wanted, for Large Boiler

Works in the Midlands, HEAD FOREMAN or ASSISTANT WORKS MANAGER. Applicant must have had experience in the production of various classes of boilers and in the control of labour. The position offers ample scope and prospect.—State age, experience and salary required, to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and L 86. No one at present on Government work will be engaged.

Wanted, for Large Boiler

Works in the Midlands, six o'clock man to act as INSPECTOR. Applicant with insurance company experience and ability to control would be preferred. The position offers good opportunity for advancement to the right man.—State age, experience and salary required, to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and L 87. No one already on Government work will be engaged.

A Well-known Engineering

Firm in the North, employing about 5000 hands, REQUIRE the services of an EXPERT to organise and assume complete control of rate fixing and estimating. Amateurs need not apply but only men of proved ability, observant, self-reliant, and above all tactful. Candidates must be thoroughly conversant with up-to-the-minute production, possess a thorough knowledge of modern machine tools, and be capable of supervising the planning out of work to give required production. State full particulars and salary required. No person already on Government work will be engaged.—Apply nearest EMPLOYMENT EXCHANGE, mentioning No. A 5099. L 118

Engineers' Storekeeper

WANTED, for Controlled Establishment, must be over 30, able to control Stores Staff and must have had previous experience.—State age, particulars of your experience, salary expected, to your nearest EMPLOYMENT EXCHANGE, mentioning this Journal and L 76. No person already employed on Government work will be engaged. L 76

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Wanted, Practical Experi-

enced ENGINEER, to undertake the Control and Management of Running Machinery in connection with this Institution. Must be ineligible for military service. Good wages paid.—Apply, SUPERINTENDENT. L 92

Up-to-date Firm in the Eastern

Counties REQUIRES the immediate service of an ENGINEER, with thorough practical training, to originate and be responsible for the design of Jigs and Tools, must have good knowledge of modern methods and capable of introducing them.—Apply, stating age, experience and salary required, to nearest EMPLOYMENT EXCHANGE, mentioning this paper and L 107. No one already on Government work can be engaged.

Engineering Firm Require

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REQUIRED immediately, Engineer and Manager for small electric supply undertaking. Diesel and Gas plant, three wire distribution.—Particulars of experience and salary required, and when duties could be commenced, to ELECTRICITY SUPPLY COMPANY, Carmarthen. L 119

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Shift Engineers for Large

private Power Station (London). Experience of Ammonia Compressors and lifts preferred. Wages £3 per week.—Address, stating age and particulars of experience, L 138, Offices of ENGINEERING.

Civil Engineer, or Good Fore-

man BUILDER, not subject to Military service, WANTED for Lagos, Nigeria, to superintend development of Shipping Depot. First-class passage, free quarters and salary corresponding to experience.—Address, with full particulars, age, experience, references and salary required, J., care of STREETS, 30, Cornhill, E.C. 3. L 111

Firm with Works in South

Coast Town REQUIRES at once practical ENGINEER as Works Manager. Small repetition work. Must have initiative and be competent in costing and modern methods of works organisation. Permanent post-war position, with excellent prospects, to suitable man.—Apply, giving full particulars and stating salary required, to L 127, Offices of ENGINEERING.

Chief Draughtsman Wanted

for Iron and Steel Works, with General Engineering experience and sound technical education preferred. No person already engaged on Government work will be employed.—Applicants should state age, experience and salary required, to nearest EMPLOYMENT EXCHANGE, mentioning No. A 5083. L 83

Wanted, in Government

Office, London, Civil Engineering ASSISTANT, experienced in Ferro-Concrete Jetty Work. Also Civil Engineering ASSISTANTS for General work. Applicants must be ineligible for General Military Service, and should give full particulars of their experience, qualifications and age, with references or copy of testimonials, and state salary required, BOX 1235, WILLINGS, 126, Strand, W.C. 2. K 964

Wanted at Once, by Large

Government Controlled Establishment, a DRAUGHTSMAN, capable of making neat sketches from actual machines. Discharged Soldier preferred. Only those not already on Government work and residing within a 10 mile radius need apply.—Address, stating age and experience, to L 45, Offices of ENGINEERING.

Draughtsman (Jig and Tool)

WANTED for large Aeroplane works in Lancashire district, knowledge of press work, tools for automatics (Cleveland and Acmes, Capstans) and all woodworking machines. No person already on Government work will be engaged. Only experienced men need apply, stating age, full experience, and salary required, at your nearest EMPLOYMENT EXCHANGE, quoting No. A 5013. L 9

Draughtsman Required to

TAKE CHARGE of Coal Washery Department. Experienced men only need apply.—Full particulars in the first place to K 624, Offices of ENGINEERING.

Good Mechanical Draughts-

MEN WANTED by large controlled firm in Manchester district. Must be quick and accurate at detail work. No person already on Government work will be engaged. Apply, with full particulars, to your nearest EMPLOYMENT EXCHANGE, mentioning No. A 4731. K 944

Draughtsman or Junior

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WHIRLING AND WHIP OF A REVOLVING SHAFT.

By G. GREENHILL.

(*Concluded from page* 388.)

15. *Lock-Nut Theory;* the invention of a device to prevent a nut from shaking loose.

The theory may be approached in the ideal manner by considering the problem of a smooth straight elastic bolt, a close fit of a tortuous hole cut through a solid block of steel.

When the rod is pushed through the hole and projects, it will work loose out at the end where the curvature is least.

If the rod is shorter than the hole and does not project, it can rest in equilibrium when curved to the same amount at each end; and the stability of the equilibrium against shaking loose requires an increase of energy of bending for a displacement each way.

The work done in bending the straight elastic rod of §6 by the opposing couples, N inch.lb, into a circular arc of curvature β radians, a radius of $\rho = \frac{l}{\beta}$ inches, in a length l inches, is $\frac{1}{2}$ N β inch-lb, the work of the average couple $\frac{1}{2}$ N acting through the angle β, and

$$\frac{1}{2}N\beta = \frac{1}{2}\frac{A\beta}{\rho} = \frac{1}{2}\frac{A}{\rho^2}\frac{l}{} = \frac{1}{2}\frac{A\beta^2}{l} \quad . \quad (1)$$

If the bolt is sprung into a curve of varying curvature, the elastic potential energy of bending is

$$\int \frac{1}{2} A \frac{ds}{\rho^2} ;$$

and if displaced through a short distance, x inches, the change of elastic energy is

$$\frac{1}{2} A x \left(\frac{1}{\rho_2^2} - \frac{1}{\rho_1^2}\right),$$

if ρ_1, ρ_2 denote the radius of curvature at the ends. Thus if $\rho_1 = \rho_2$, there is no change of energy, and the bolt is in equilibrium.

But to the second order of x,

$$\Delta \frac{1}{\rho^2} = -\frac{2x}{\rho^5}\frac{d\rho}{ds}, \quad . \quad . \quad . \quad . \quad (2)$$

so that the change of energy is

$$\frac{A x^2}{\rho^5}\left(\frac{d\rho_1}{ds} - \frac{d\rho_2}{ds}\right), \quad . \quad . \quad . \quad . \quad (3)$$

and this must be positive to ensure stability.

Then if v is the velocity acquired in slipping back to the position of equilibrium, the equation of energy

$$W\frac{v^2}{2g} + \frac{A x^2}{\rho^5}\frac{d(\rho_1 - \rho_2)}{ds} = \text{constant} \quad . \quad (4)$$

shows that the bolt, of weight W lb, oscillates like the simple equivalent pendulum of length

$$\frac{W\rho^5}{2A\frac{d(\rho_1 - \rho_2)}{ds}} \quad . \quad . \quad (5)$$

16. The calculation of the moment about O y of the C.F. on the half curve A C B is given, in the notation of the Integral Calculus, by

$$\int \frac{w}{\sin\alpha}\cdot\sin\theta\frac{b\omega^2}{g}b\,d\theta\,x = \frac{w}{\sin\alpha}\frac{b^2 p}{l}\int_{\frac{1}{2}\pi}^{\frac{1}{2}\pi}\theta\sin\theta\,d\theta = \frac{2w}{\sin\alpha}\frac{b^2 p}{l} \quad (1)$$

has been quoted already in §3 in the graphical representation of Fig. 2, page 387 *ante*, of the first moment about O y for the area O B D, and it is evaluated by an ordinary integration, assuming

$$\theta\sin\theta = \frac{d}{d\theta}(\sin\theta - \theta\cos\theta).$$

But the following geometrical demonstrations are submitted of these integrations required here, for the interest of the instructor called on to face a class unversed in the Calculus, which should be considered pathetic in these days of the technical college.

Thus it is not with the intention of supplanting the orthodox methods; because it has been well said before "It is easier to learn the Calculus than to follow a method which seeks to avoid the study of its notation and method." But the alternate method will appeal to the mind of a careful thinker, anxious to reach the foundation of the theory.

Draw the sine curve O P B in Fig. 1, page 273 *ante*, graph of

$$y = a\sin\frac{x}{p} = a\sin n\,x = a\sin\theta,\ \theta = n\,x = \frac{x}{p} \quad (2)$$

$np = 1$, so that n or p is employed as best suited to the notation in avoiding a fractional form in printing.

This curve is the projection on the plane x O y of a quarter wave of the helix, O C $= a$, O E $= p$.

The area element

$$\left.\begin{aligned} &dA = y\,dx = \text{P M}\,.\,mm' = \text{O N}\,.\,rr' = \text{K L}\,.\,rt \\ &= \text{elementary rectangle } kl', \text{ because } \frac{\text{O N}}{\text{K L}} = \sin\theta = \frac{rt}{rr'} \end{aligned}\right\} (3)$$

Thus the area O M P and the rectangle E K grow together from zero at the same rate, by equal increments pm' and kl', and so they are always equal; hence the graphical representation of the integral of $\sin\theta = \sin\frac{x}{p} = \sin n\,x$;

$$\text{Area O M P} = \int_0 y\,dx = a\int_0 \sin n\,x\,dx = \text{rectangle E K}$$
$$= pa(1 - \cos\theta) = pa\ \text{vrs}\,n\,x \quad . \quad . \quad (4)$$

and the area O D B of the quarter wave = rectangle E C $= pa$.

Thus the pitch p is the mean length C G measured along C B of the area O D B, of height a.

For a graphical representation of the first moment of the area O M p, given by the integral summation

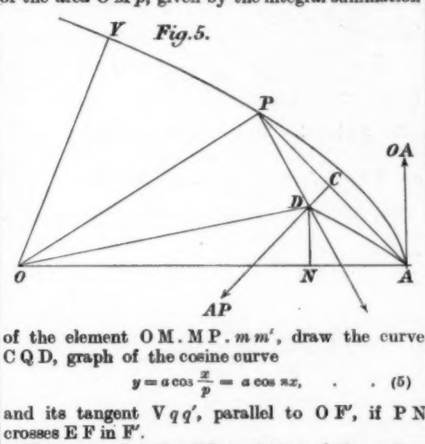


Fig.5.

of the element O M . M P . mm', draw the curve C Q D, graph of the cosine curve

$$y = a\cos\frac{x}{p} = a\cos nx, \quad . \quad . \quad (5)$$

and its tangent V qq', parallel to O F', if P N crosses E F in F'.

Then assuming the differentiation of the cosine,

$$\frac{d}{dx}a\cos\frac{x}{p} = -\frac{a}{p}\sin\frac{x}{p},\ \frac{d}{dx}a\cos nn = -na\sin nx, \quad (6)$$

implied however in the integration in (4),

$$\text{H V} = x\frac{a}{p}\sin\frac{x}{p} = \frac{\text{OM . MP}}{\text{OE}}, \quad . \quad . \quad (7)$$

$$\text{O M . M P}\,.\,m\,m' = \text{O E . H V},\ zz' = p\ \text{area}\ zq\,q'z'$$
$$= p\ \text{area}\ ghk'q',$$

so that the moment about O y of the area O M P and p times the arc C H Q grow from zero at the same rate by equal increments, and so are always equal. Thus the moment of the quarter wave O B D is p times the area O C D or O D B of the quarter wave; and the area being pa, the C.G. of O D C is at a distance p from O C, and is the same as the mean ordinate, and is in the line parallel to O y in Fig. 1, page 273, and Figs. 2 and 4, page 387 *ante*, through the inter-section of the tangents at O and B of the sinusoid, and thus obvious otherwise from statical principles.

These are the Lemmas required in the determination of the wrench (force and couple) of the C.F. on a halfwave length of the helix, or any other fraction of the length.

17. If the shaft is revolving free between the bearings in a uniform helix of slight deflection and small angle a, with L $= 0$, X $= 0$ in (7) §9,

$$\left(\frac{2\pi}{\lambda}\right)^4 = n^4 = \frac{m}{\text{A L}} = \frac{w\,\text{K}}{w\,\text{E K}\,k^2 l} = \frac{1}{e\,k^2 l},\ \lambda = 2\pi^4\sqrt{(e\,k^2 l)}; \quad (1)$$

and this gives the solution of the length of shaft between bearings at which whirling begins; or if the shaft is still, it gives

$$\omega^2 = \frac{g}{l} = n^4 e\,k^2 g = \left(\frac{2\pi}{\lambda}\right)^4 e\,k^2 g \quad . \quad . \quad (2)$$

and

$$N = \frac{\omega}{2\pi} = \frac{2\pi\sqrt{(e\,k^2 g)}}{\lambda^2} = 2\pi\sqrt{\frac{e\,k^2 g}{\lambda^4}} \quad . \quad (3)$$

the number of lateral double vibrations/second, if the shaft is plucked or sprung, and then let go, beating time with a pendulum of length

$$\left(\frac{\lambda}{2\pi}\right)^4 \frac{1}{e\,k^2} = \frac{p^4}{e\,k^2}.$$

Putting U $= \sqrt{(g\,e)}$, the velocity, inches/sec, of longitudinal vibration of sound along the shaft, and V the velocity of waves of lateral vibration of length λ in a shaft of unlimited length, not held in bearings,

$$\text{V} = \lambda\,\text{N},\ \frac{\text{V}}{\text{U}} = \frac{2\pi k}{\lambda},\ \text{varying inversely as wave length } \lambda.$$

The group velocity of such waves is 2 V, the ripples run over the long waves, and make them appear to advance with double velocity.

18. *Group Velocity.*—Waves at sea and generally everywhere are not pure waves, but composed of a blend of waves of nearly equal wave length, so that an individual wave is in a state of growth or decay.

In a procession of a blend of two waves of nearly equal wave length, the elevation of the surface may be taken as

$$\left.\begin{aligned} y = y_1 + y_2 &= b_1\sin\frac{2\pi}{\lambda_1}(\text{V}_1 t - x) + b_2\sin\frac{2\pi}{\lambda_2}(\text{V}_2 t - x) \\ &= \frac{1}{2}(b_1 \pm b_2)\left[\sin\frac{2\pi}{\lambda_1}(\text{V}_1 t - x) \pm \sin\frac{2\pi}{\lambda_2}(\text{V}_2 t - x)\right] \\ &= (b_1 \pm b_2)\begin{matrix}\sin\\\cos\end{matrix}\pi\left[\left(\frac{\text{V}_1}{\lambda_1} + \frac{\text{V}_2}{\lambda_2}\right)t - \left(\frac{1}{\lambda_1} + \frac{1}{\lambda_2}\right)x\right] \\ &\qquad \begin{matrix}\cos\\\sin\end{matrix}\pi\left[\left(\frac{\text{V}_1}{\lambda_1} - \frac{\text{V}_2}{\lambda_2}\right)t - \left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right)x\right] \end{aligned}\right\} (1)$$

as before in §8.

Here the waves are given by

$$\begin{matrix}\sin\\\cos\end{matrix}\pi\left[\left(\frac{\text{V}_1}{\lambda_1} + \frac{\text{V}_2}{\lambda_2}\right)t - \left(\frac{1}{\lambda_1} + \frac{1}{\lambda_2}\right)x\right] \begin{matrix}\sin 2\pi\\\cos 2\pi\end{matrix}(\text{V}\,t - x) \quad (2)$$

when the waves are so nearly equal that we may take $\lambda_1 = \lambda_2 = \lambda$, $\text{V}_1 = \text{V}_2 = \text{V}$, and these waves run like ripples over the long waves given by

$$\begin{matrix}\cos\\\sin\end{matrix}\pi\left[\left(\frac{\text{V}_1}{\lambda_1} - \frac{\text{V}_2}{\lambda_2}\right)t - \left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right)x\right] \quad . \quad . \quad (3)$$

of length the reciprocal of $\frac{1}{2}\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right)$, and of period the reciprocal of $\frac{1}{2}\left(\frac{\text{V}_1}{\lambda_1} - \frac{\text{V}_2}{\lambda_2}\right)$, both large; but moving with a finite velocity

$$\text{G} = \frac{\frac{\text{V}_1}{\lambda_1} - \frac{\text{V}_2}{\lambda_2}}{\frac{1}{\lambda_1} - \frac{1}{\lambda_2}} = \frac{d\frac{\text{V}}{\lambda}}{d\frac{1}{\lambda}} = \text{V} - \lambda\frac{d\,\text{V}}{d\,\lambda} \quad . \quad . \quad (4)$$

this G is called the "group velocity."

If V varies as some power q of λ,

$$\frac{d\,\text{V}}{d\,\lambda} = q\frac{\text{V}}{\lambda},\ \text{and G} = (1 - q)\,\text{V}. \quad . \quad (5)$$

Thus in the case above of waves of lateral vibration in an elastic bar, $q = -1$, G $= 2$ V.

In deep sea waves, $q = \frac{1}{2}$, G $= \frac{1}{2}$ V.

In short capillary waves, $q = -\frac{1}{2}$, G $= \frac{3}{2}$ V, as we see on the surface of water when a stone is thrown and produces a series of circular concentric waves, dark and bright patches travelling over the capillary waves.

19. When the shaft is revolving free between the bearings in any uniform helix of flexure due to centrifugal force, the waves can be obtained in the same elementary manner as for the slack rope in §10, by equating the bending couples at the end of the half wave to the moment of the C.F.; and then

$$2A\frac{\sin^2\alpha}{b}\cos\alpha = 2\frac{m}{\sin\alpha}\frac{b^2 p}{l} = 2m\frac{a^3}{l}\sin\alpha\cos\alpha \quad (1)$$

$$\frac{A}{a^2} - \frac{m}{l} = 0,\ a^4 - \frac{l\,A}{m} = \frac{l\,E\,k^2}{w} = l\,e\,k^2 \quad . \quad (2)$$

as before in §16, with L $= 0$, X $= 0$, but with any value of a, not restricted to be small.

If V is the velocity of advance of these helical waves,

$$\text{V} = \lambda\,\text{N},\ \frac{\text{V}}{\text{U}} = \frac{2\pi k}{\lambda}\cos\alpha \quad . \quad . \quad (3)$$

20. *Lévy's Elastica*, leading up to Tube Collapse (Math. Annalen, LII., 1898; I.N.A. 1900, page 116, vol. XLII.; Southwell in Proc. R.S., January, 1913).

Starting from a point A (Fig. 5.) of maximum or minimum curvature of the curve AP of cross-section of a tube exposed to uniform external pressure q, the shearing force at A is zero, and the resultant force tangential, and may be represented by q . O A,

measuring a finite length A O along the normal at A, as in Fig. 5.

The resultant fluid thrust across any arc A P is q . chord A P, acting at right angles to the chord through its midpoint C.

The anti-resultant of q . O A and q . A P will be a force q . O P, acting at right angles to O P.

But if the force q . O P meets the resultant fluid thrust in D, the two forces combine into a resultant q . O A through D at right angles to O A; and so there will be a couple q . O A. A N over, to be balanced by the difference of the bending moment (B.M.) at A and P.

Denoting them by M_A and M_P

$$\left.\begin{aligned} M_A - M_P &= q\,.\,OA\,.\,AN = \tfrac{1}{2}q\,(OA^2 + AD^2 - OD^2) \\ &= \tfrac{1}{2}q\,(OA^2 + PD^2 - OD^2) = \tfrac{1}{2}q\,(OA^2 - OP^2) \end{aligned}\right\} \quad (1)$$

On the elastic theory that the alteration in the curvature is proportional to the bending moment.

$$M_A - M_P = A\left(\frac{1}{\rho_0} - \frac{1}{\rho}\right), \quad . \quad . \quad (2)$$

where ρ, ρ_0 denotes the radius of curvature at P, A, and A denotes as before the flexural rigidity, $A = E\,K\,k^2 = \frac{1}{12}\,E\,t^3$, on the usual theory, for a thickness t inches, A being reckoned per inch run of tube length.

Thence from the expression

$$\frac{1}{\rho} = \frac{d\,p}{r\,d\,r} = \frac{1}{\rho_0} - \frac{\frac{1}{2}q}{A}\left(a^2 - r^2\right) \quad . \quad . \quad (3)$$

$$\frac{d\,p}{d\,r} = \frac{\frac{1}{2}q}{A}\,r^3 + \left(\frac{1}{\rho_0} - \frac{\frac{1}{2}q\,a^2}{A}\right)r \quad . \quad . \quad (4)$$

$$p = \alpha\,r^4 + \beta\,r^2 + \gamma \quad . \quad . \quad . \quad (5)$$

by integration, where

$$\alpha = \frac{q}{8\,A},\ \beta = \frac{1}{2\,\rho_0} - \frac{q\,a^2}{4\,a},\ 4\,\alpha\,a^3 + 2\,\beta\,a = \frac{a}{\rho_0}. \quad . \quad (6)$$

Then, for the arc s of the curve,

$$\tfrac{1}{2}\left(\frac{dr^2}{ds}\right)^2 = r^2\left(\frac{dr}{ds}\right)^2 = r^2 - p^2 = r^2 - (\alpha\,r^4 + \beta r^2 + \gamma)^2 = R \quad (7)$$

suppose, giving r^2 as a uniform elliptic function of s.

The further integration in the general case is discussed in Halphen's "Fonctions elliptiques, t. II, Chap. V, and in the "Mathematische Annalen," 52, 1898.

21. *Tube Collapse.*—In the practical problem of the collapsing pressure of a circular tube of radius a, $r^2 - a^2$ is a factor of R, and a repeated factor if

$$4\,\alpha\,a^3 + 2\,\beta\,a = 1,\ \rho_0 = a \quad . \quad . \quad . \quad (1)$$

where the tube has been rolled to keep at the radius a, and then we find

$$\left.\begin{aligned} \left(\frac{a\,d\,r^2}{d\,s}\right)^2 &= 4\,a^2\,R = \\ -(8\,\alpha\,a^3 + 1)\,(r^2 - a^2)^2 &- 4\,\alpha\,a\,(r^2 - a^2)^3 - 4\,a^2\alpha^2(r^2 - a^2)^4 \end{aligned}\right\} \quad (2)$$

the negative sign showing that the only solution is $r^2 = a^2$, and the circular form is stable, as in the corresponding problem of the stability of a circular orbit. And for the determination of the apsidal angle when disturbed slightly, add a small constant for the penultimate term when $r^2 - a^2$ is allowed a little play, and differentiate

$$\frac{a^2}{r^2 - a^2}\,\frac{d^2\,(r^2 - a^2)}{d\,s^2} = -8\,\alpha\,a^3 - 1 - 6\,\alpha\,a\,(r^2 - a^2) - 8\,a^2\,\alpha^2\,(r^2 - a^2)^2 = -8\,\alpha\,a^3 - 1. \quad . \quad (3)$$

$$r^2 - a^2 = P\sin n\,\frac{s}{a},\ \text{where } n^2 = 8\,\alpha\,a^3 + 1 \quad (4)$$

with an apsidal angle $\frac{\pi}{n}$.

For an unsupported circular tube, n must be an integer, 2, 3, 4, . . . , the number of waves round the circumference.

For collapse into two waves, $n = 2$,

$$8\,\alpha\,a^3 = n^2 - 1 = 3,\ q\,a^3 = 3\,A = \tfrac{1}{4}\,E\,t^3,\ \frac{q}{E} = \tfrac{1}{4}\left(\frac{t}{a}\right)^3 \quad (5)$$

the well known formula. For historical references consult Love's "Theory of Elasticity."

Thus with a diameter 50 times the thickness, the collapsing pressure of a steel tube will be about 60 lb/inch^2, diminishing rapidly with heating.

In an alternative treatment of the collapse of a tube into circumferential waves lying between the radius a and b, not requiring the plate to be rolled, to the radius of the tube, but bent from the flat or any other curvature, we take

$$p = \alpha\,r^4 + \beta\,r^2 + \gamma,\ \text{with } p,\ r = a,\ \text{and } p,\ r = b \quad (6)$$

and thence by algebraical reduction—

$$\beta = \frac{1}{a+b} - a\,(a^2 + b^2),\ \gamma = \frac{a\,b}{a+b} + A\,a^2\,b^2 \quad (7)$$

$$\left(\frac{d\,\frac{1}{2}\,r^2}{d\,s}\right)^2 = R = r^2 - p^2 = a^2\left[\left\{r^2 - \frac{a^2 + b^2}{2} + \frac{1}{a\,(a+b)}\right\}^2 - \left(\frac{a^2 - b^2}{2}\right)^2 + \frac{a+b}{a}\right](a^2 - r^2)\,(r^2 - b^2) \quad (8)$$

giving s in terms of r^2 by the elliptic integral of the first kind; and then, by the inversion, r^2 is given as a uniform elliptic function of s.

In the practical problem, when collapse begins from the circular section, a and b are nearly equal, and $r^2 - \frac{1}{2}\,(a^2 + b^2)$ can be considered insensible, and $a = b$; then R reduces to the form—

$$R = \left(\frac{1}{4\,a^2} + 2\,a\,A\right)(a^2 - r^2)\,(r^2 - b^2) \quad (9)$$

$$n\,\frac{d\,s}{a} = \frac{d\,r^2}{\sqrt{(a^2 - r^2\,.\,r^2 - b^2)}},\ \text{with } n^2 = 1 + 8\,a^3\,A \quad (10)$$

$$a^2 - r^2 = (a^2 - b^2)\cos^2\tfrac{1}{2}\,n\,\frac{s}{a},$$

$$r^2 - b^2 = (a^2 - b^2)\sin^2\tfrac{1}{2}\,n\,\frac{s}{a} \quad . \quad . \quad (11)$$

and when n is an integer, the circumferential curve closes on itself in n waves.

The case of $n = 1$ would imply a slight sidelong displacement of the cross-section without distortion; so we take $n = 2, 3, 4, \ldots$; and then $8\,a^3\,\alpha = n^2 - 1$, with $\alpha = \dfrac{q}{E\,I}$, and $I = \dfrac{1}{12}\,t^3$ per inch length of the tube, for a thickness t inches.

$$\frac{q}{E} = \frac{n^2 - 1}{96}\left(\frac{t}{a}\right)^3 = \frac{n^2 - 1}{12}\left(\frac{t}{d}\right)^3, \text{ that is, } \tfrac{1}{4}\left(\frac{t}{d}\right)^3 \quad (12)$$

for $n = 2$ and a diameter d inches.

Thus with E = 30 million lb/in^2, and $\dfrac{t}{d} = \dfrac{1}{100}$, $q = 7{,}5$ lb/in.^{2}, or $\dfrac{t}{d} = \dfrac{1}{50}$, $q = 60$ lb/in^2.

But if E is reduced to 10 million lb/in^2 in consequence of overheating of the flue, the collapsing pressure is reduced to 2.5 or 20 lb/in^2.

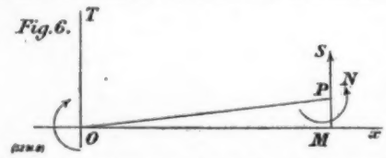


Fig. 6.

If the tube is strengthened by rings, the number of waves may change to 3, 4, . . . ; and end thrust will also have an influence on the nature of the collapse, as investigated by Southwell, *Phil. Trans.*, 1913.

Illustrative experiments can be carried out with short tubes, such as the nickel case of a bullet, compressed in a vice.

Similar manifestations of stability-instability are seen everywhere in Nature, in the vibration of a blade of grass, a cornstalk, a tree, the Eiffel Tower. Over-correction of resilience is required for stability, in the vibration on each side of equilibrium.

27. The tail end of a shaft will begin to whip in the same manner as the lateral vibrations.

Consider the equilibrium of the length O P in Fig. 6, whirled round bodily with A.V. ω, with slight displacement, sprung slightly. The curve here is a plane curve of varying curvature, and cannot be replaced by the uniform helix and treated by an elementary method as before.

The resources of the Calculus must be invoked.

The difference of the bending moments at P and O, N and N_0, is balanced by the moment of the shearing force S at P, less the moment of the C.F. round O.

Across a plane section K at P, the C.F. does not act through P, but at a distance above, $\dfrac{k^2}{y}$; so that the equation is

$$N - N_0 = x\,S\,m\,\frac{\omega^2}{g}\int\left(x - \frac{k^2}{y}\,\frac{d\,y}{d^2}\right)y\,d\,x \quad . \quad (1)$$

an integral-differential equation; in which

$$N = A\,\frac{d^2\,y}{d\,x^2},\ S = -\frac{d\,N}{d\,x} = -A\,\frac{d^3\,y}{d\,x^3}. \quad . \quad (2)$$

Differentiating,

$$x\,\frac{d^2\,N}{d\,x^2} + \frac{m}{l}\left(x\,y - k^2\,\frac{d\,y}{d\,x}\right) = 0 \quad . \quad . \quad (3)$$

an intractable equation.

But in the case of a thin shaft, where it is permissible to neglect the term with k^2, the equation reduces to

$$A\,\frac{d^4\,y}{d\,x^4} - \frac{m}{l}\,y = 0, \quad . \quad . \quad . \quad (4)$$

of which the general solution is

$$y = C_1\,\mathrm{ch}\,n\,x + C_2\,\mathrm{sh}\,n\,x + D_1\cos n\,x + D_2\sin n\,x \quad (5)$$

with

$$A\,n^4 - \frac{m}{l} = 0,\ n^4 = \frac{m}{A\,l}, \quad . \quad . \quad (6)$$

as in §16, with L = 0, X = 0, where the solution was discussed for C_1, $C_2 = 0$.

In the tail shaft, the condition

$$y = 0,\ \frac{d\,y}{d\,x} = 0 \text{ at } x = 0 \text{ requires } C_1 + D_1 = 0,\ C_2 + D_2 = 0 \quad (7)$$

$$y = C_1\,(\mathrm{ch}\,n\,x - \cos n\,x) + C_2\,(\mathrm{sh}\,n\,x - \sin n\,x) \quad (8)$$

To satisfy the conditions at the free end of a shaft, overhanging a length $x = h$,

$$N = A\,\frac{d^2\,y}{d\,x^2} = 0,\ S = A\,\frac{d^3\,y}{d\,x^3} = 0 \quad . \quad (9)$$

$$n^2\,C_1\,(\mathrm{ch}\,n\,h + \cos n\,h) + n^2\,C_2\,(\mathrm{sh}\,n\,h + \sin n\,h) = 0 \quad (10)$$

$$n^3\,C_1\,(\mathrm{sh}\,n\,h - \sin n\,h) + n^3\,C_2\,(\mathrm{ch}\,n\,h + \cos n\,h) = 0 \quad (11)$$

and eliminating $C_1 : C_2$, and putting $n\,h = q$,

$$(\mathrm{ch}\,q + \cos q)^2 - (\mathrm{sh}^2\,q - \sin^2 q) = 0,\ \mathrm{ch}\,q\cos q + 1 = 0$$
$$\tan\tfrac{1}{4}\,q\,\mathrm{th}\,\tfrac{1}{4}\,q = \pm 1 \quad . \quad . \quad (12)$$

But with a lump of M lb at the tail end,

$$N = 0,\ C_1\,(\mathrm{ch}\,q + \cos q) + C_2\,(\mathrm{sh}\,q + \sin q) = 0 \quad (13)$$

$$S = M\,\frac{y}{l} = A\,\frac{d^3\,y}{d\,x^3} = A\,n^3[C_1\,(\mathrm{sh}\,q - \sin q) + C_2\,(\mathrm{sh}\,q + \cos q)] \quad . \quad . \quad (14)$$

$$-\frac{C_2}{C_1} = \frac{\mathrm{ch}\,q + \cos q}{\mathrm{sh}\,q + \sin q} = \frac{M\,(\mathrm{ch}\,q - \cos q) - A\,l\,n^3\,(\mathrm{sh}\,q - \sin q)}{M\,(\mathrm{sh}\,q - \sin q) - A\,l\,n^3\,(\mathrm{ch}\,q + \cos q)} \quad . \quad (15)$$

$$\frac{A\,l\,n^3}{M} = \frac{A\,l}{M\,h^3}\,q^3 = \frac{\mathrm{ch}\,q\sin q - \mathrm{sh}\,q\cos q}{\mathrm{ch}\,q\cos q + 1} \quad . \quad (16)$$

When the weight of the shaft can be neglected, and q is small, the conditions reduce to

$$\frac{d^4\,y}{d\,x^4} = 0,\ y = C_1\,x^2 + C_2\,x^3,\ \frac{A\,l}{M\,h^3} = \frac{1}{3},\ l = \frac{1}{3}\,\frac{M\,h^3}{A} \quad (17)$$

so that l is the same as the deflection produced by the dead weight M at the end, in accordance with a general principle.

But if the lump M is the screw, loose and free to revolve with angular momentum (A. M.) H, or else clamped to the shaft, then S is the same as before in (14), but instead of N = 0, we have to equate N to the velocity of the vector of the A.M. of the screw.

23. Begin with a screw of uniaxial symmetry, with three or more blades, and denote its axial and diametral moment of inertia by I_1 and I_2, lb-inch^2; so that the corresponding components of A. M. are $I_1\,\frac{\omega}{g}\cos\delta$, $I_2\,\frac{\omega}{g}\sin\delta$ if the end is sprung at an angle δ; and the component A.M. perpendicular to the axis of rotation will be

$$(I_2 - I_1)\,\frac{\omega}{g}\sin\delta\cos\delta, \quad . \quad . \quad . \quad (1)$$

and equating its vector velocity to the couple,

$$A\,\frac{d^2\,y}{d\,x^2} = N = (I_2 - I)\,\frac{\omega^2}{g}\sin\delta\cos\delta = \frac{I_2 - I_1}{l}\sin\delta\cos\delta, \quad (2)$$

in which we can put $\cos\delta = 1$, $\sin\delta = \tan\delta = \dfrac{d\,y}{d\,x}$ at $x = h$; so that

$$\begin{aligned} &A\,l\,n^2[C_1\,(\mathrm{ch}\,q + \cos q) + C_2\,(\mathrm{sh}\,q + \sin q)] \\ &+ (I_1 - I_2)\,n\,[C_1(\mathrm{sh}\,q + \sin q) + C_2\,(\mathrm{ch}\,q - \cos q)] = 0 \end{aligned} \quad (3)$$

together with (14) §21,

$$\begin{aligned} &A\,l\,n^3[C_1\,(\mathrm{sh}\,q - \sin q) + C_2\,(\mathrm{ch}\,q + \cos q)] \\ &+ M\,[C_1\,(\mathrm{ch}\,q - \cos q) + C_2\,(\mathrm{ch}\,q - \sin q)] = 0 \end{aligned} \quad (4)$$

$$-\frac{C_2}{C_1} = \frac{(I_1 - I_2)\,(\mathrm{sh}\,q + \sin q) + A\,l\,n\,(\mathrm{ch}\,q + \cos q)}{(I_1 - I_2)\,(\mathrm{ch}\,q + \cos q) + A\,l\,n\,(\mathrm{sh}\,q + \sin q)} = \frac{M\,(\mathrm{ch}\,q - \cos q) + A\,l\,n^3\,(\mathrm{sh}\,q - \sin q)}{M\,(\mathrm{sh}\,q - \sin q) + A\,l\,n^3\,(\mathrm{ch}\,q + \cos q)} \quad (5)$$

$$\left[\frac{I_1 - I_2}{A\,l}\,(\mathrm{sh}\,q + \sin q) + \frac{q}{h}\,(\mathrm{ch}\,q + \cos q)\right] \times \left[\mathrm{sh}\,q - \sin q + \frac{A\,l}{M\,h^3}\,q^3\,(\mathrm{ch}\,q + \cos q)\right] - \left[\frac{I_1 - I_2}{A\,l}\,(\mathrm{ch}\,q - \cos q) + \frac{q}{h}\,(\mathrm{sh}\,q + \sin q)\right] \times \left[\mathrm{ch}\,q - \cos q + \frac{A\,l}{M\,h^3}\,q^3\,(\mathrm{sh}\,q - \sin q)\right] = 0 \quad (6)$$

To obtain the result for $m = 0$, as in the *Report on Gyroscopic Theory*, p. 271, expand in power of q;

the series begins with q^4, the coefficient of which must be equated to zero, and we obtain, as before in the *Report*

$$\frac{I_2 - I_1}{\frac{1}{2}A} = \frac{l}{k}\frac{12\,A\,l - 4\,M\,k^3}{12\,A\,l - M\,k^3} \quad . \quad . \quad (7)$$

24. Mr. Fage, in ENGINEERING, July 20, 1917, considers the more general dynamics of a two-bladed screw, revolving at high speed.

With two blades, O B, O C a screw is not kinetically symmetrical about the axis, as we have assumed above with three blades and more; the momental ellipsoid is not one of revolution about the axes, but has three unequal principal moments of inertia, I_1, I_2, I_3, lb-inch², about the principal axis O x, O B, O C, the axis O x of the shaft being assumed a principal axis.

In Fig. 7 the screw is right handed, and seen as a tractor screw as viewed by the airman sitting behind it, with its axis along O x and horizontal, O y vertical, O z to the right, on a right-handed screw system of axes.

The machine is supposed to be turning to the left with component A. V. Q about O y, and the screw is revolving about O x with A.V. P, and A.M. (angular momentum) $h_1 = I_1\frac{P}{g}$, sec-inch-lb. and the K.E. of this rotation is $I_1\frac{P^2}{2g}$, inch-lb.

Steering to the left, with A.V.Q, the components of A.V. and A.M. about the axis O x of the blades are

$$P = \frac{d\phi}{dt}, \quad Q\cos\phi, \quad -Q\sin\phi,$$

and

$$I_1\frac{P}{g}, \quad I_2\frac{Q}{g}\cos\phi, \quad -I_3\frac{Q}{g}\sin\phi,$$

equivalent to components of A.M.

$$h_1 = I_1\frac{P}{g}, \text{ about } Ox,$$

$$h_2 = (I_2\cos^2\phi + I_3\sin^2\phi)\frac{Q}{g}, \text{ about } Oy,$$

$$h_3 = (I_2 - I_3)\sin\phi\cos\phi\,\frac{Q}{g}, \text{ about } Oz.$$

The components L, M, N, inch-lb, of the couple acting on the screw required to make it take up its motion are the components of the velocity of the vector of A.M.,

$$L = \frac{dh_1}{dt} + Qh_3, \quad M = \frac{dh_2}{dt}, \quad N = \frac{dh_3}{dt} - Qh_1, \quad . \quad (1)$$

the first term in L and N due to the rate of growth of h_1 and h_3, and the second term to the swing of h_3 and h_1;

$$M = -(I_2 - I_3)\frac{PQ}{g}\sin 2\phi, \quad N = (I_2 - I_3)\frac{PQ}{g}\cos 2\phi - I_1\frac{PQ}{g} \quad (2)$$

With a screw of more than two blades,

$$I_2 = I_3, \text{ and } M = 0, \quad N = -I_1\frac{PQ}{g}, \quad . \quad (3)$$

meaning that the screw reacts on the frame with a couple-vector O E, tending to make the machine soar and rise when turning to the left.

But with the two-bladed screw, the vector couple of reaction on the frame is given by O F, where $\frac{E\,F}{O\,E} = \frac{I_2 - I_3}{I_1}$, and O E F $= 2\phi$, hence the vibration experienced in a flying machine with a two-bladed screw, due to the rapid variation of the couple vector O F.

25. Mr. Fage investigates the whip in a tail shaft carrying a two-bladed propeller at the end; but he assumes the shaft is sprung into a plane curve, which will not be the case with the varying couple of reaction; and the tortuous shape assumed would be changing continually, and defy analytical calculation.

With three or more blades spaced equally, $I_2 = I_3$, and the result has been given above.

In Mr. Fage's numerical applications he uses the name *slug*, newly invented by Professor Perry for the engineer's unit of mass, a 32.2 lb weight; and measured in this unit,

$$I_2 = 3.5, I_3 = 0.02, I_1 = I_2 + I_3 = 3.25, \text{ slug-ft}^2 \quad . \quad (1)$$

ignoring the axial extension of weight in the thickness of the screw.

These numbers require to be multiplied by 32.2 and 144 to bring them into our unit of the lb-inch², making in round numbers

$$I_1 = 196{,}000, I_2 = 195{,}000, I_3 = 1{,}000, \text{ lb-in}^2 \quad . \quad (2)$$

Here I_3 is so small by comparison it may be neglected, equivalent to treating the two blades as a thin rod stuck through the shaft; and then the vector O F′ of the couple of centrifugal reaction lies in O B, and describes a circle passing through O;

$$O\,F' = I_2\frac{2\,P\,Q}{g}\sin\phi = 1{,}000\,P\,Q\sin\phi, \text{ in-lb.} \quad (3)$$

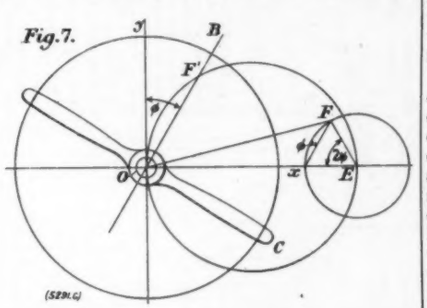
At 1,800 revolutions per minute (r.p.m.) we take P = 5 radians / second, and Q = 0.2 for a horizontal circle described in 30 seconds, making P Q = 1.

26. Slug is a curious name to give to a 32-lb shot.

Ibsen's *Wild Duck* is said to be carrying about in her body a brace of slugs, and these could hardly be Perry slugs.

Andrew Noble's slug would at this rate be a 32-ton gun, employed with the unit pressure in artillery of the ton/inch².

Returning to the foot in the measurement of axial advance, the equation of motion of a w lb shot, which has acquired velocity v f/s in an advance x feet in t seconds up his smooth bore experimental



100 calibre, d inch, gun, under a powder pressure of p tons/inch², would be

$$\frac{w}{2240}\frac{d^2x}{g\,d\,t^2} = \frac{w}{2240}\frac{v\,d\,v}{g\,d\,x} = \tfrac{1}{4}\pi\,d^2\,p, \text{ tons} \quad (1)$$

and the energy acquired is obtained by integration;

$$\frac{w}{2240}\frac{v^2}{2\,g} = \int \tfrac{1}{4}\pi\,d^2p\,d\,x, \text{ ft-tons} \quad . \quad . \quad (2)$$

and Sir Andrew writes m for $\frac{w}{2240g}$, so that his unit mass is 2240 g lb or g tons.

Professor Perry is acclaimed to have made an important advance in dynamical theory for practical men by the invention of his name *slug* for the engineers' unit of mass, a g lb weight; as great a step as when Professor James Thomson invented the name *poundal* for the absolute unit of force on the Imperial foot-pound-second (F.P.S.) system, inculcated in academic theoretical instruction on the Professor Tait tradition, as the only permissible system in teaching elementary dynamics; although Tait could not carry his colleague Thomson with him, in the collaboration of a Treatise on Natural Philosophy.

But between slug and poundal the ordinary mathematical novice is bound to come to grief and confusion. Ask him for instance the poundals to the slug in a dynamical problem in the field of gravity in which we live.

The units employed in mechanics and dynamics must be kept under careful observation; and here the Hospitalier notation employed above is of great assistance for the derived units.

In giving any numerical result we never omit to state the unit, as 12 inches, 32 lb. But when the algebraical symbol is employed, the temptation is to write a length x, a weight w, a force P, with the unit omitted, so that the algebraical formula should be suitable whether inches and lb were employed, or cm and kg.

An indefinite statement, such as —a mass m acted on by a force P —would be clarified if amended more distinctly as —a mass m (grammes, lb, tons, slugs, Perry or Noble slugs, . . .) acted on by a force P (dynes, poundals, tonals, pounds, tons, kg. . . .).

Hence much of the vagueness in the text book and writings on mechanics, and an easy way of avoidnig it.

TEMPLETS, JIGS AND FIXTURES.—No. III.

By JOSEPH HORNER.

THE subject of this article is the application of jigs, gauges, and templets to the work of steam turbine manufacture as carried out by the firm of Messrs. J. Samuel White and Co., Limited, of East Cowes, Isle of Wight. This class of work is characterised by massiveness and by a very considerable amount of complication, and an immense amount of detail. A very high grade of accuracy is required, yet the use of the fixture is impracticable, both because of the large dimensions of the main castings and fittings, and also on account of the large numbers of related details which have to be tooled. The scheme that is adopted in all cases by this firm is well illustrated in the examples shown. It is employed in engines of various sizes, and for high, low, and intermediate pressure casings. These, in different designs and dimensions, have many variations in their details, but the general methods will be obvious from the examples selected for illustration.

The general scheme may be stated first. The cylinder to be treated is outlined in a skeleton form only, that is, all its interior details, the bored dimensions and other parts which are not "jigged" or templated, are omitted. Only those parts which are so dealt with are outlined. The bewildering mass of sectional details, and of dimensions which crowd the drawings of turbine engines being omitted here, do not obscure the work of the marker off, and the jig setter, and driller. Examples selected are those of a high-pressure casing, Figs. 53 to 55, page 418, and a low-pressure casing, Figs. 60 to 63, page 419.

On the outline drawing of the cylinder, Figs. 53 to 55, three sets of elements are tabulated with symbols and reference letters that correspond with letters on the drawings, each set of letters having also its numbers for identification. The elements are standard lengths, symbol L; jigs, symbol J; templets, symbol T; by which the workman can distinguish at once the meaning of a reference, while the numbers following show the particular location and use. Every detail is worked from dimension lines, and from centre lines, which are marked on the casting, and correspondingly on the jigs and templets. And on both, it is stated which side must join the casing, and whether it goes on top, or bottom, or forward, or aft, according to the position of the face.

The tabulated references given, when compared with the corresponding references on the drawings, call for few elucidating remarks. Taking the standard lengths L first; these, it will be seen, are all cardinal lengths, and centre lines by which the templets and jigs are set and centred. This is work for the liner-off. Following this the templets T are set by their centre lines on the corresponding lines on the casting, and are used for marking holes through in feet and various flanges, against which it is not convenient or is not necessary to affix jigs. The latter, J, are of cast-iron, bushed with hardened steel, some further references to which are given later.

Taking the jigs in order, the first is J1, through which the holes are drilled in the main steam branches A, A, the faces of which are measured from the aft face of the casing—the distance L1, Fig. 54. Their centres are seen in Fig. 55, L5, from the centre, and L7 down from the joint face. The jig is shown in this figure as laid against the flange faces, and in outside view below. It is 1¼ in. thick and bushed for fifteen 1¼-in. holes. The top of the jig is indicated, as the holes are not alike relatively to the centre lines. The jig J2, Fig. 56 is for the cruising steam branch, seen at B in Figs. 54 and 55. A similar jig, Fig. 57, is used for the exhaust branches C, C, in Figs. 54 and 58. Jigs J4 are employed to drill the holes in the bye-pass

GAUGES, JIGS AND TEMPLETS FOR HIGH-PRESSURE TURBINE CASING.

Fig. 53.

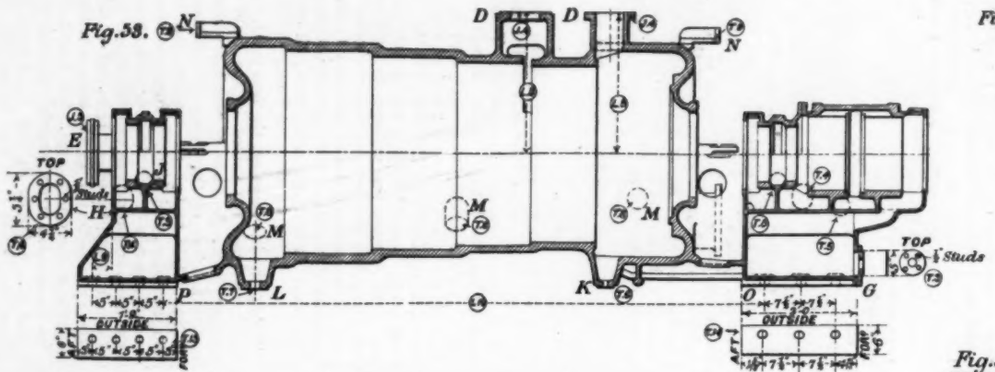


Fig. 54.

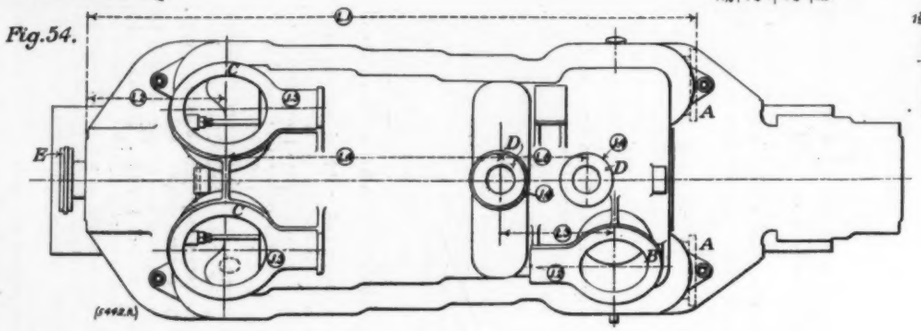


Fig. 55.

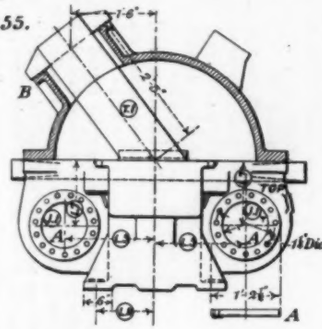


Fig. 58.

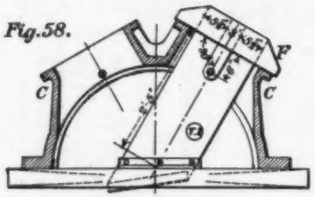


Fig. 59.

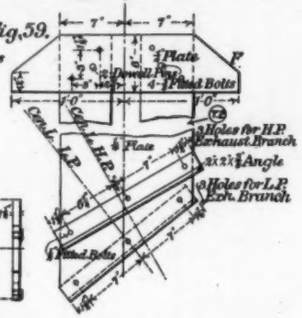


Fig. 57.

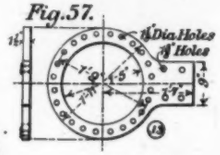
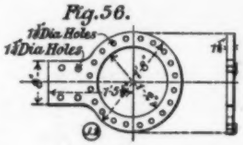


Fig. 56.



STANDARD LENGTHS.

No.	Purpose.	Length.
L. 1	Horizontal distance from aft face of cylinder to steam branch	10 ft. 7 in.
L. 2	Horizontal distance from aft face to C.L. of exhaust branch	2 ft. 5 in.
L. 3	Horizontal distance from C.L. of bye branch to C.L. of cruising steam branch	2 ft. 0 in.
L. 4	Horizontal distance from C.L. of bye branch to C.L. of exhaust branch	4 ft. 8½ in.
L. 5	Horizontal distance from C.L. of cylinder to main steam branches	1 ft. 7 in.
L. 6	Horizontal distance between centres of bye-pass branches	1 ft. 5½ in.
L. 7	Vertical distance from cylinder joint to main steam branches	1 ft. 1½ in.
L. 8	Vertical distance from cylinder joint to bye-pass branch	2 ft. 5 in.
L. 9	Horizontal distance from aft : face of cylinder to after holding down bolt centre	4 ft. 0 in.
L. 10	Horizontal distance between inner holding down bolt centres	10 ft. 4⅛ in.
L. 11	Horizontal distance from C.L. of cylinder to C.L. of holding down bolts	1 ft. 0½ in.

NOTE.—These standard lengths may be taken from contractors' own measuring machines.

JIGS.

No.	Purpose.	Bushes. Hole Dia.	Bushes. Collar.
J. 1	Main steam branch	1⅛ in.	1⅝ in. × ½ in.
J. 2	Cruising steam branch	1⅛ in. and 1⅜ in.	(1⅝ in. and 1⅞ in.) × ⅛ in.
J. 3	Exhaust branches	1⅛ in. and 1⅜ in.	(1⅝ in. and 1⅞ in.) × ½ in.
J. 4	Bye-pass facings	See L.P. and astern.	
J. 5	Rotor shaft coupling	See coupling jig drawing.	

TEMPLATES

No.	Purpose.
T. 1	Angle and position of cruising steam branch (see I.P. cruising).
T. 2	Angle and position of exhaust branches.
T. 3	Oil drain.
T. 4	Oil drain.
T. 9	Gland valve box facing (see H.P. cruising).
T. 14	Cylinder foot (forward).
T. 15	Cylinder foot (aft).

facings D, D, Figs. 53 and 54, and another, J5, for the rotor shaft coupling E in Figs. 53 and 54.

The templets T1 and T2, Figs. 55, 58 and 59, check respectively the position of the steam branch B in Fig. 54, and of the exhaust branches C, C, in the same figure. They check the angles of the faces of the flanges of those branches. They are of 1¼-in. plate, Fig. 59, and are set by the axial centre line of the cylinder, with which the centre line of the templet must coincide. A strip of angle iron bolted on the main plate lines on a straight-edge laid across the face of the joint of the casing, and the edge of the transverse plate F, at the top makes contact with the face of the flange. The one templet serves for the steam and the exhaust branches, having two strips of angle iron, Figs. 58 and 59, bolted to it.

The remaining templets T, are of a minor character, being for marking stud holes through. T3 locates four stud holes for an oil drain on the facing G, Fig. 53. T4, of an elliptical form, for a similar facing at H on the same figure. T5 to T7 are for oil supply and cylinder drain faces at J, K and L respectively. T8 is for a gland exhaust facing M. T9 is for a gland valve-box facing. T14 and T15 are for the cylinder feet O and P.

The casing for the low-pressure and astern cylinders is outlined in Figs. 60 to 63, with its machining instructions, as in the high-pressure cylinder. The standard lengths L on the drawings may be compared with the table. The jigs J are as follows: J3, that for the steam branch A, Figs. 61 and 63, is shaped like Figs. 56 and 57. J4 is for the auxiliary exhaust branch B, Figs. 60 and 61. It is seen edgewise in Fig. 60. J5 is for the rotor-shaft coupling at C, C, Fig. 60. This design was illustrated in the last article. J6, the jig for drilling the ahead manœuvring steam branch D, is shown in Fig. 63. The main exhaust branch E, Figs. 60 and 61, is drilled through the jig J7, which is seen edgewise in Fig. 60. J8 drills the astern steam branch F, Figs. 61 and 62. J9, the cylinder end flanges G, Figs. 60 and 63. The jig is shown in Figs. 64 and 65, page 420. J10, the thrust facing H, Figs. 61 and 63, for the ahead main steam strainer.

The templets T repeat nearly the functions of those noted in connection with the high-pressure cylinder. T2, for the steam branch A, Figs. 61 and 63, resembles that in Figs. 58 and 59. The utilities of the remainder need not be specified, since they are stated in the list and resemble those in the previous group.

The gear cases are drilled on the end flanges with jigs. Each engine has its gear-case, the lower portion of which is a casting, the upper being a covering of sheet iron with flanges of angle iron. The jigs concern the lower part of the casting only. The holes in the case have to match those in the aft end of the turbine. Two examples are shown, Figs. 66 to 71, on page 420. In these the central joint face of the case stands at an angle that is included in the jig.

The jig, Figs. 66 to 68, is for a high-pressure turbine. It is of cast-iron, and its opposite faces are laid on the gear-case, and the bearing block of the engine which the case has to fit. The holes drilled thus match exactly like those drilled in the shaft coupling joints shown in the last article. As studs are fitted in some holes, and clearing holes and fitting bolts in others, the bushes are changed in the jig. For fitting bolts the same bushes are used in gear-case and engine casing. For stud bolts they are changed. The bushes are shown in Figs. 72 to 74 for fitting-bolt holes, for clearing holes, and for tapping respectively. There is a spigot on the forward end of the gear-case where it

GAUGES, JIGS AND TEMPLETS FOR LOW-PRESSURE AHEAD AND ASTERN TURBINE CASINGS.

Fig. 60.

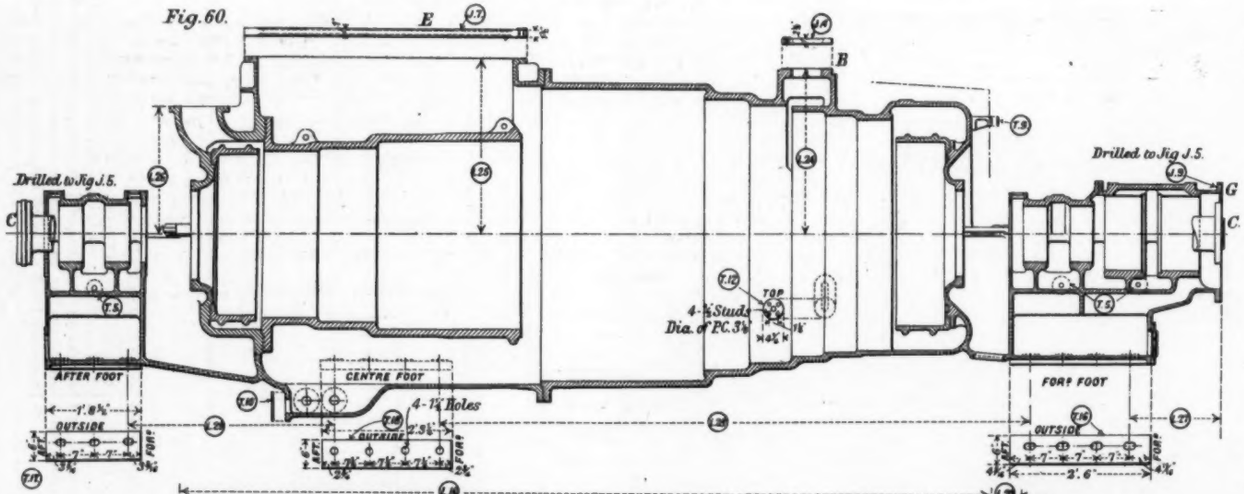


Fig. 61.

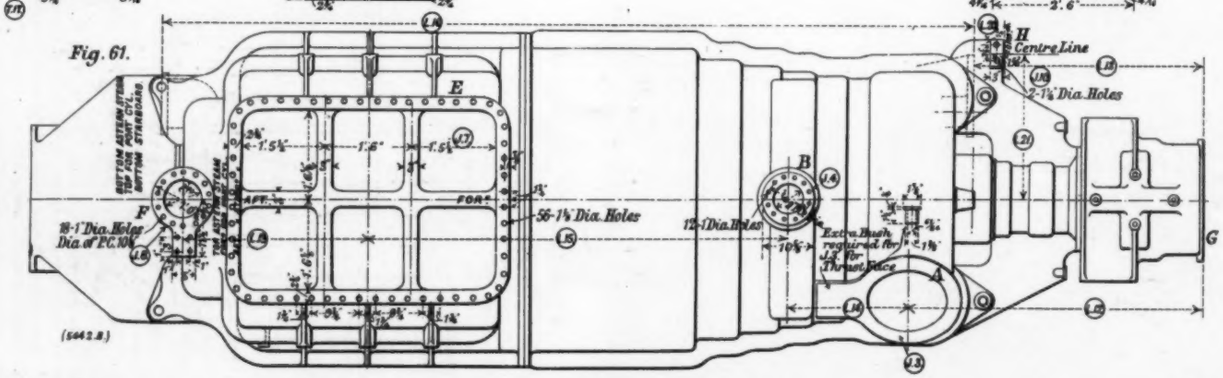


Fig. 62. END VIEW LOOKING FORWARD.

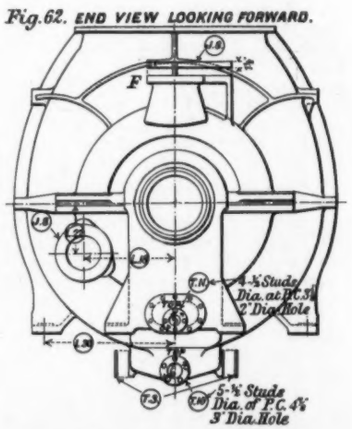
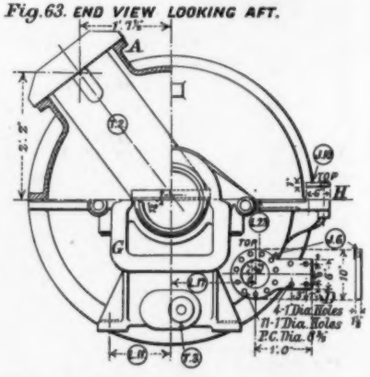


Fig. 63. END VIEW LOOKING AFT.



JIGS.

	Purpose.	Bushes. Hole Dia.	Collar.
J. 3.	Steam branch. See H.P. ahead	1½ in.	1⅝ in. × ⅛ in.
J. 4.	Auxiliary exhaust branch	⅝ in.	1⅛ in × ⅛ in.
J. 5.	Rotor shaft coupling	See coupling jig drg.	
J. 6.	Ahead manœuvring steam branch	⅝ in.	1⅛ in. × ⅛ in.
J. 7.	Main exhaust branch	¾ in.	1⅛ in. × ⅛ in.
J. 8.	Astern steam branch	⅝ in.	1⅛ in. × ⅛ in.
J. 9	Cylinder end flanges	See H.P. cruisg. drg.	
J. 10	Thrust facing for ahead manœuvring steam strainer	¾ in.	1⅛ in. × ⅛ in.

NOTE.—Jigs to be made of cast iron. Bushes to be made of case hardened steel.

TEMPLATES.

	Purpose.
T. 2.	Position and angle of steam branch. See H.P. ahead.
T. 3.	Facing on drain well and oil drain forward end.
T. 5.	Oil supply.
T. 9.	Gland valve box facing. See H.P. cruising.
T. 10.	After facing on drain well.
T. 11.	Oil drain aft end.
T. 12.	Facing for gland leak off connection.
T. 16.	Cylinder foot (forward).
T. 17.	Cylinder foot (aft).
T. 18.	Cylinder centre foot.

NOTE.—Centre lines to be clearly marked on jigs and templates, also which side joins cylinder and top or bottom, forward or aft, according to position of face.

STANDARD LENGTHS.

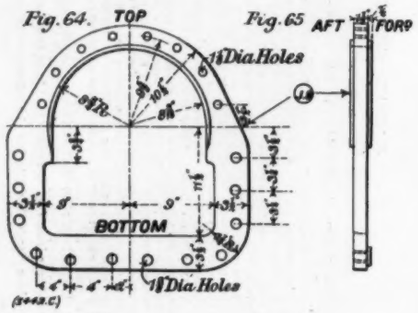
	Purpose.	Length. ft.	in.
L. 11.	Horizontal distance from C.L. of turbine to C.L. of forward and after foot H.D. bolts. See H.P. ahead	1	0
L. 12.	Horizontal distance from forward face of cylinder to steam branch	5	1½
L. 13.	Horizontal distance from forward face of cylinder to manvg. branch	4	0½
L. 14.	Horizontal distance from C.L. of steam branch to auxiliary exhaust branch	2	1⅛
L. 15.	Horizontal distance from main exhaust branch to auxiliary exhaust branch	7	3⅛
L. 16.	Horizontal distance from ahead manvg. steam branch to bottom astern steam branch	14	2⅜
L. 17.	Horizontal distance from C.L. of cylinder to ahead manvg. steam branch	1	6
L. 18.	Horizontal distance from C.L. of cylinder to bottom astern steam branch	1	7½
L. 19.	Horizontal distance from C.L. of main exhaust to top astern steam branch	1	2½
L. 20.	Horizontal distance from manvg. steam branch to thrust face	0	5½
L. 21.	Horizontal distance from C.L. of cylinder to C.L. of thrust face	2	6½
L. 22.	Vertical distance from cylinder joint to bottom astern branch	0	10½
L. 23.	Vertical distance from cylinder joint to ahead manvg. steam branch	1	3
L. 24.	Vertical distance from cylinder joint to auxiliary exhaust steam branch	2	10
L. 25.	Vertical distance from cylinder joint to main exhaust steam branch	3	0
L. 26.	Vertical distance from cylinder joint to top astern steam branch	2	2
L. 27.	Horizontal distance from forward face of cylinder to forward holding down bolt centre	1	7⅛
L. 28.	Horizontal distance from after H.D. bolt centre in forward foot to forward H.D. bolt centre in centre foot	10	3½
L. 29.	Horizontal distance from after H.D. bolt centre in centre foot to forward H.D. bolt centre in aft foot	3	6⅛
L. 30.	Horizontal distance from C.L. of turbine to C.L. of turbine to C.L. of centre foot H.D. bolts	2	3½

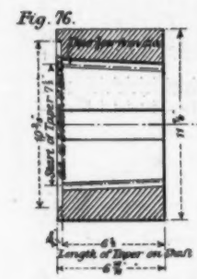
NOTE.—These standard lengths may be taken from contractors' own measuring machines.

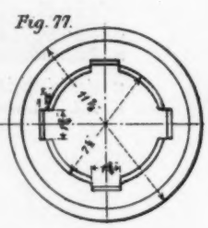
Joins the turbine casing. The jig is located by means of this, the recessed shoulder A, Figs. 68 and 71, fitting over the spigot.

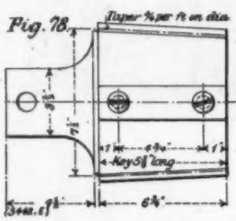
The upper face of the jig is covered by a steel plate, the lower face of which lies in the plane of the joint of the case. When the joint lies at an angle there are two plates, one of which corresponds with the horizontal axis of the case, the other with the diagonal joint. The relations of these are seen in Fig. 70, the two plates being marked C and D respectively. For the angle of the main joint of the gear case, a sheet metal templet, Fig. 75, is provided.

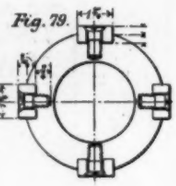
Gauges for rotor spindle and clutch tapers are shown by Figs. 76 to 79. These, representative of others, resemble those shown in the last article for the tapers on propeller shafts and in propeller

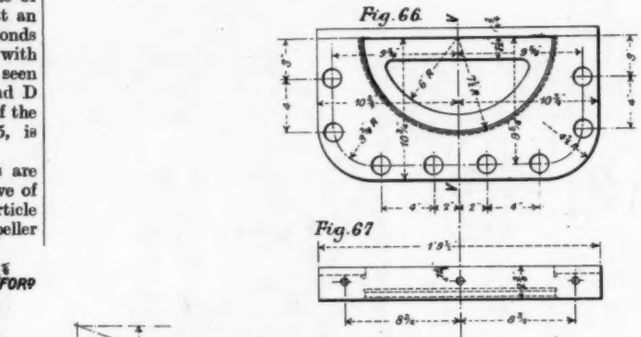


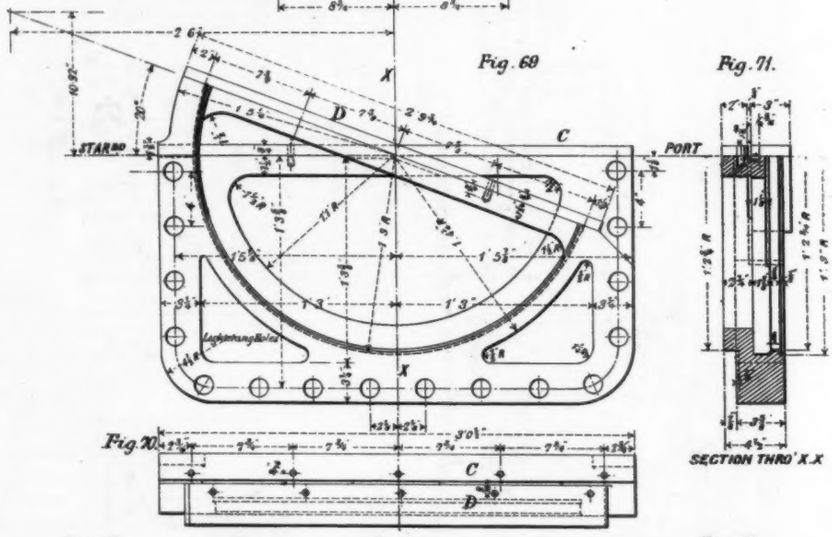


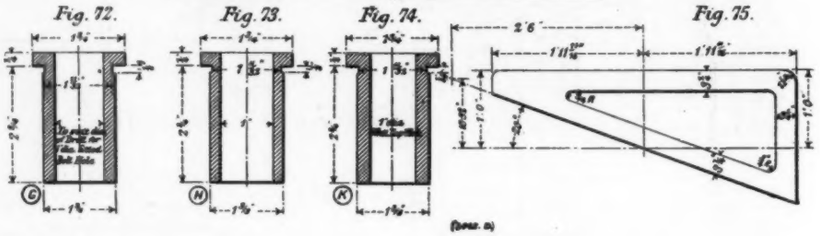


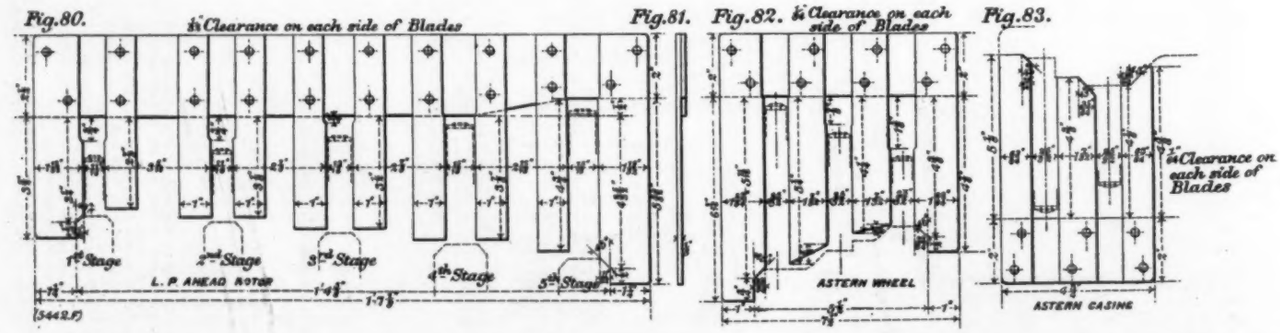












bosses. They vary in dimensions only, with the sizes of the shafts, high-pressure, intermediate-pressure, or low-pressure engines. The two examples shown are for external and internal use on low-pressure rotor spindles. The gauge, Figs. 76 and 77, fits over the spindle, and its keys, that go—Figs. 78 and 79—into the clutch coupling, including the key grooves. The key strips are of steel let into recesses and screwed. The bodies of the gauges are of cast-iron. The gauge, Fig. 78, has a hole through its boss by which it is suspended over the hole which it tests.

Figs. 80 to 83 show gauges used for checking the blades of rotors. The illustrations show their functions. Strips or tongues of steel $\frac{1}{4}$ in. thick pass between the blades with from $\frac{1}{32}$ in. to $\frac{3}{64}$ in. of clearance to permit of freedom of insertion and removal. At the ends they make contact with locations on the rotor.

The use of gauges and templets on ordinary repetition work has, of course, long been recognised shop practice. The application to turbines which can hardly be considered manufactured articles marks, however, a further stage in advance. Indirectly the adoption of the system is advantageous in that it puts pressure on the drawing office to standardise components and fittings as far as possible. Moreover, although skilled men can do remarkably accurate work without the aid of special jigs, the use of jigs and gauges results in a great saving of time, a commodity in which economy is of national importance at the present moment. Moreover, the adoption of the system often enables a real craftsmen to be reserved for special work.

TRIPLE-EXPANSION PUMPING ENGINES FOR THE LONDON COUNTY COUNCIL.

CONSTRUCTED BY MESSRS. FULLERTON, HODGART AND BARCLAY, LTD., PAISLEY, TO THE DESIGNS OF MR. H. M. ROUNTHWAITE.

(*For Description, see Page* 422.)

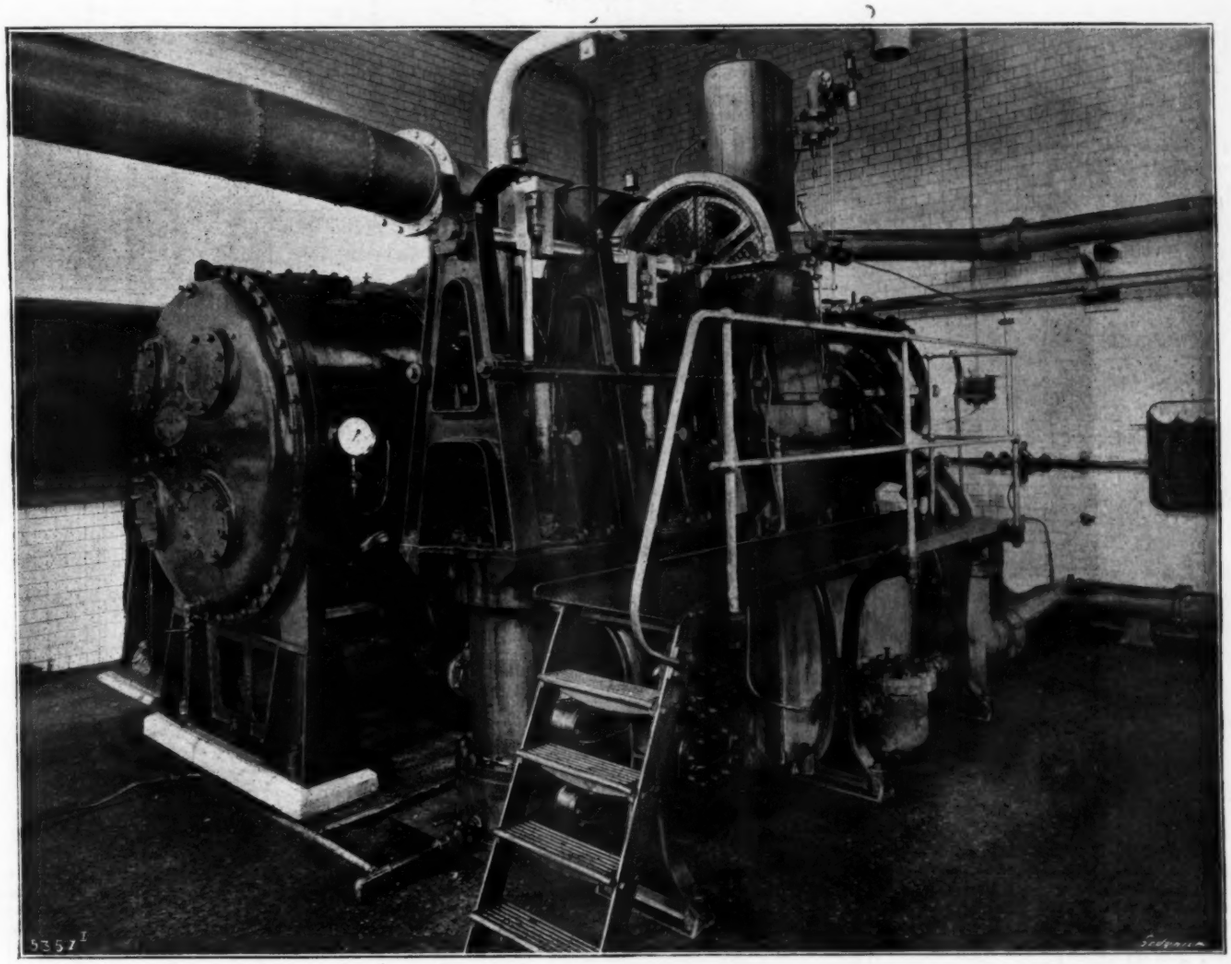


FIG. 24. ONE SET OF CONDENSING PLANT.

ZINC REFINING IN THE UNITED STATES.

BEFORE the war zinc refining in the United States had almost been limited to remelting the zinc of relatively high-lead percentage from the retort furnaces, the slab dross and the hard spelter from galvanising pots. The product of these operations, though known in the trade as Prime Western zinc, is only considered a fourth or fifth-grade metal, and the specifications for virgin spelter, which are to be voted upon by the American Institute of Mining Engineers, in June next, would leave it in the latter position. Owing to the presence of lead in most zinc ores, the bulk of the American spelter is of the Prime Western grade. Cartridge brass and other high-grade brass should be free of lead, though a certain small amount of lead facilitates clean cutting in brasses which are to be machined. The enormous war demand for cartridge brass hence depreciated the Prime Western grade, and zinc refining both by redistillation and by electrolysis received a great impetus. Of the common impurities of spelter, lead, iron, cadmium, lead is the most objectionable, and in ordinary distillation a certain proportion of the lead, which may amount to 10 per cent. in zinc concentrates, will pass into the zinc. If the ores contain as much iron as lead, the danger of contamination is smaller; the iron does not distil, but is apt to be scraped or to be carried into the condenser from the mouth of the retort. Cadmium, of which about 0.3 per cent. occurs in the zinc ores, is found mainly in the "first-draw" spelter from the condenser, as cadmium is more volatile than zinc. On the proposed specification to which we alluded, the grades would be distinguished as: high, intermediate, brass special, selected, Prime Western, and the admissible lead percentages would be: 0.07, 0.2, 0.6, 0.8, 1.6; the iron percentage would vary between 0.03 and 0.08, the cadmium percentage between 0.07 and 0.75. A uniformity of grade is more difficult to secure than one might think, because the temperature of the retorts varies during the distillation, and varies also in the different rows of the retorts of a furnace. The various means now in use for obtaining a pure zinc by distillation were reviewed by Mr. Leland E. Wemple, metallurgist of the American Zinc, Lead and Smelting Company, of St. Louis, Mo., in the November Bulletin of the American Institute of Mining Engineers. The means appear rather crude and unsatisfactory, particularly also in hygienic respects; but many metallurgical operations leave much to be desired in this respect unfortunately. Mr. Wemple's information on American practice may be interesting as a complement to our recent article on the British spelter industry (ENGINEERING, February 15 and 22, 1918).

The first method referred to by Wemple consists in placing a dam or filter in the mouth of the retort or in the butt of the condenser. The filter is a porous pack, made up of grains of refractory material, of coal or coke, or simply of the last shovel of the charge, being essentially coke. A dam similarly consists of fireclay or coke. The vapours of zinc and cadmium pass through these filters whilst the less volatile lead and the iron remain in the retort. But the introduction of the filter must reduce the total yield of metal; there is the further danger that zinc vapours first condense inside the dam and are overheated and escape uncondensed at a later stage; in any case the porous material will soon become clogged with charge dust, blue powder and metal. The recently suggested mode of briquetting the charge aimed at a similar purpose. The charge was briquetted into circular discs, nearly as big as the diameter of the retort, which were cored at the centre for charging on a rod. These briquettes were troublesome, however, and smaller bricks also disintegrated and failed to act as filters.

The spelter-refining by redistillation is mainly carried out according to two methods, those of G. M. Holstein and J. D. James, of 1896, and of C. A. H. de Saulles whose patent was only granted in 1917. By both these methods the zinc is redistilled in retorts so inclined that the lead collects in the lower butt end which is cooled by being exposed to the air. In this way unsaleable zinc used to be refined to a limited extent for twenty years already, as we stated in our introduction; but during the last three years the use of refining has been much extended; either existing smelting furnaces have been converted and adapted to this refining, or special furnaces have been designed, and it is from this point of view that the two methods have to be distinguished. In order to convert an ordinary ore-smelting and distilling furnace into a redistilling furnace the lower row of retorts is removed, and the butts of the upper rows of retorts are placed on the shelves of the next row below, which gives the retort an inclination of about 10 in. in its length and permits it to hold a bath of molten spelter. As the temperature required for redistillation is not so high as the temperature needed for smelting, the natural gas (generally used) is burnt under its natural draught. The back wall of the retort is an outer wall which is provided with an opening to admit the air that is to cool the butt;

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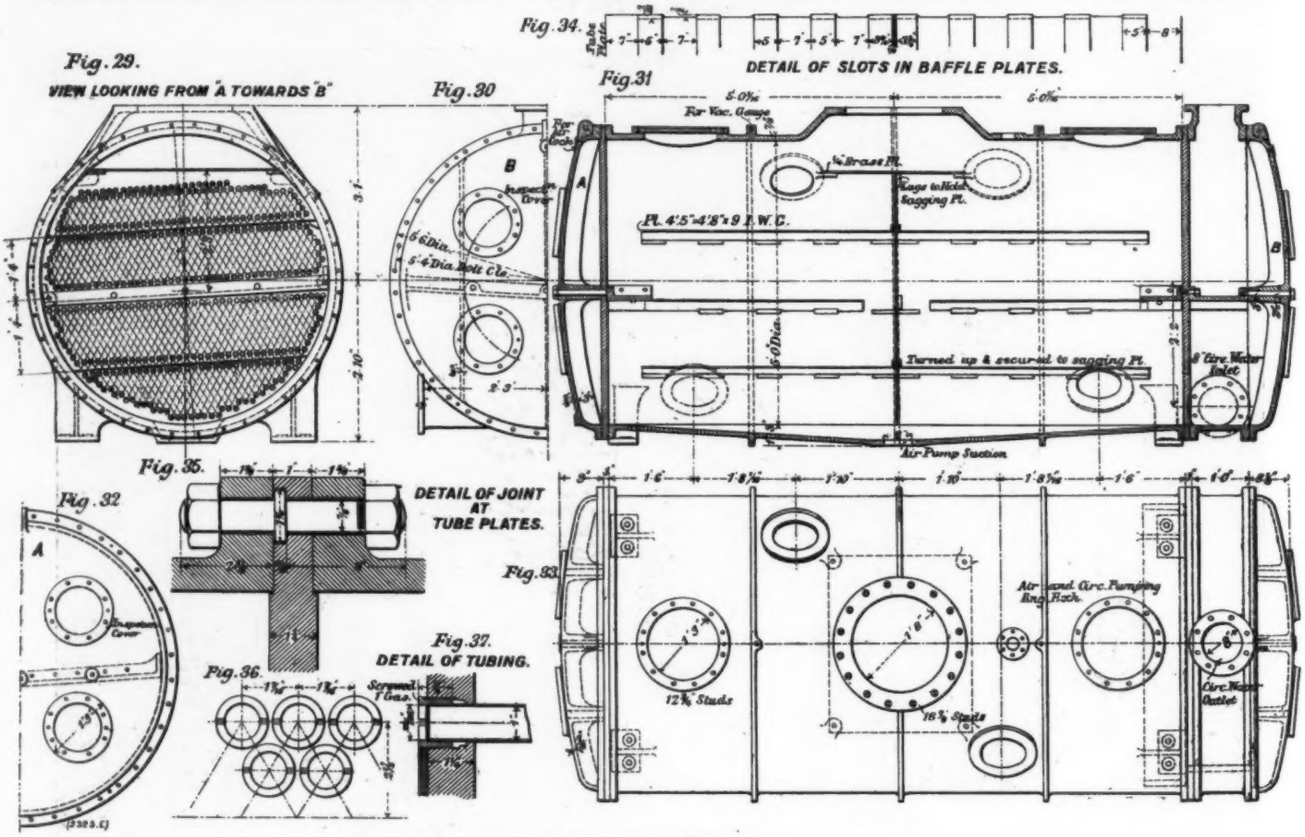

FIGS. 29 TO 37. THE CONDENSER.

water jackets may also be used for cooling. The condenser, which is luted into the mouth of the retort, is generally a truncated cone which is provided with an external dam near the smaller end (7 in. diameter) while the larger outer end (10 in. diameter) is closed by a fireclay plate provided with semi-circular openings at the top and bottom. Through the top hole the charge, in the shape of sticks of crude spelter, is introduced while the distillation is proceeding. The cast sticks are 20 in. long, and 1¼ in. by 1 in. in section, and weigh about 10 lb. each; four or five sticks make a charge, and are pushed in over the dam. The holes are then stuffed, and in 10 minutes the distillation from that particular retort will have restarted. The condensers are drawn every 6 hours or less; the top hole is carefully spiessed first, lest the gas pressure force the vapours and liquid metal out. After a while lead and iron will have accumulated in a retort; such a retort is then not charged, but is scraped the next day after removing the condensers.

With this arrangement the bottom row of the retorts of a furnace is not utilised; the capacity of a furnace of 608 retorts, *e.g.*, is reduced to 456 retorts, and the furnace requires considerable alterations and is difficult of access. The process of de Saulles makes use of a specially constructed furnace which is equivalent to one side of an ordinary furnace block. The inclined retorts are extended through the back wall, so that the butt protrudes by about 5 in. The butt end is provided with a charging hole at the top and a smaller tapping opening; during the redistillation these holes are plugged. There are two, three or four rows of retorts, and from 80 to 200 retorts in a furnace. The retorts are charged with molten spelter from a ladle suspended from a chain block, and this charging is renewed every 24 hours, one row in the morning, the other in the evening; the holes are reclosed immediately, and the temperature is kept up for 24 hours. The condensers are drawn every 4 hours; the lead is tapped once every 48 hours; every 10 days the retorts are tapped completely dry. The lead thus obtained contains 1 per cent. or 2 per cent. of zinc and is sold to lead refiners. The grade of the resulting zinc of the two methods is about the same. Starting with a spelter containing 1.5 per cent. to 3 per cent. of lead, 0.03 per cent. to 1 per cent. of iron, 0.03 per cent. to 0.07 per cent. of cadmium, the lead is generally reduced to 0.03 per cent. or 0.12 per cent., the iron to 0.012 per cent., and the cadmium is little affected. The resulting grade is a good intermediate or high. To secure that grade, care must be taken always to have a sufficient excess of zinc in the retort and to keep the heating uniform, lest "hot spots" develop and lead vapours be liberated. The retorts hold nearly 300 lb. of molten metal; in the furnace of de Saulles, 175 lb. of molten metal are charged per retort at one time in 24 hours, while in the first method mentioned the charging takes place at 6 hours' intervals. In both the methods the waste of retorts and the metal losses in the retorts are serious; the retorts are severely strained by the heavy charges of metal; they crack, and vapour and fused metal escape into the furnace, and are carried off as zinc oxide through the smoke stack. According to Wemple, retorts made under very heavy hydraulic pressures in Wettengel presses last 60 days, against the 20 days or 30 days of retorts produced by ordinary presses.

TRIPLE-EXPANSION PUMPING ENGINES FOR THE LONDON COUNTY COUNCIL.

(*Concluded from page* 363.)

The condenser sets formed part of the same contract. One of them is illustrated complete in Fig. 24 on the preceding page, and in details in Figs. 29 to 37, above. Each set comprises a condenser, air pump, and circulating pump, driven by a tandem compound engine, of the design shown in Figs. 27 and 28, Plate XLI. Each condenser has 3,000 sq. ft. of tube surface. The tubes are 1 in. in diameter and about 10 ft. long. They are of No. 16 gauge and are of the Admiralty mixture. The relatively large diameter of the tubes was adopted in order to facilitate the frequent cleanings necessary owing to the dirty condition of the circulating water. The exhaust pipes from the engine to the condenser are necessarily somewhat long, and special care was taken to avoid expansion troubles and to secure efficient drainage. The condenser bodies are of cast-iron and the interior is divided up by horizontal diaphragms passing between the tubes and arranged to give departmental drainage. A vertical diaphragm-plate giving support to the tubes at about mid-length is also fitted, and both the tube plates and diaphragm plates are of rolled brass. The bolts and studs for all internal joints are of manganese bronze.

The air pumps are of the ordinary vertical pattern. They are driven by spur gearing from the crankshaft of the engine which drives the circulating pump, as shown in Figs. 25 and 26, Plate XLI. This is of the centrifugal type, and has to operate against a fairly high effective head since the level of the sprinklers through which the cooling water is ultimately discharged, is about 10 ft. above the surface of the water in the ponds, and the discharge pipe has a length of about 530 ft.

Under the chief engineer of the London County Council (Mr. G. W. Humphreys), Mr. H. M. Rounthwaite (Mechanical Engineer), and his staff, have been responsible for the design, construction and erection of the machinery described.

WINCOTT FURNACES.

THE war, which has produced a number of innovations and developments in engineering, has, due to the call for a large increase in the output of steel of all kinds, especially shell steels and those required for munitions of war, encouraged furnace builders, to provide new and larger furnaces. In meeting this requirement they have had an opportunity of examining their designs with a view to the introduction of improvements and at the same time of so altering details of construction as to reduce the first cost as well as the cost of maintenance. The provision of well-constructed and economical furnaces, although of great importance at the present time, is by no means a requirement for the period of the war only; it is therefore an opportune time to give particulars and illustrations of some successful furnaces which have been or are being installed by Messrs. G. P. Wincott, Limited, of Sheffield, in steelworks and factories in

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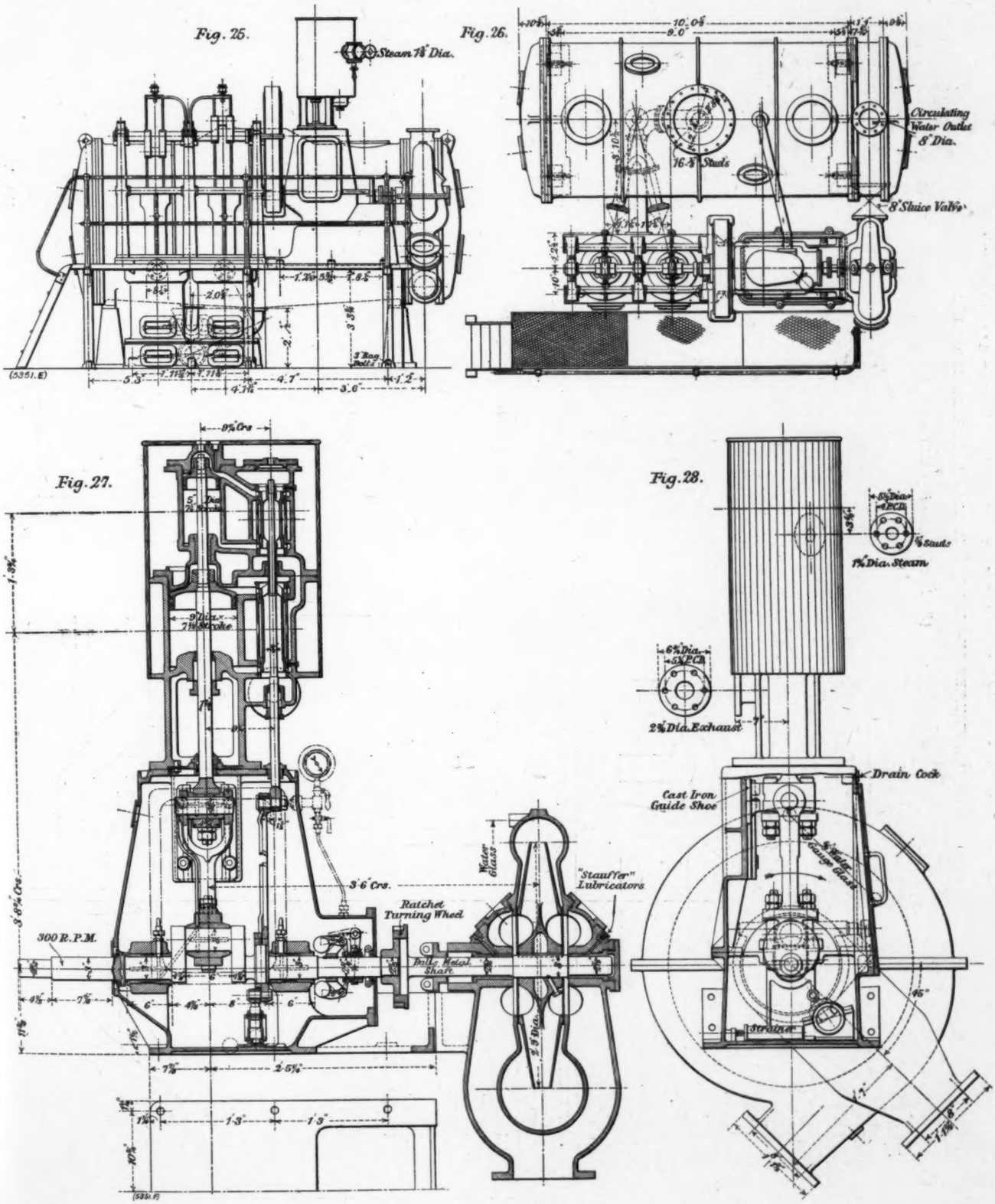
CONSTRUCTED BY MESSRS. FULLERTON, HODGART AND BARCLAY, LTD., PAISLEY, TO THE DESIGNS OF MR. H. M. ROUNTHWAITE.

(*For Description, see Page 422.*)



FIGS. 25 TO 28. THE CONDENSING PLANT.

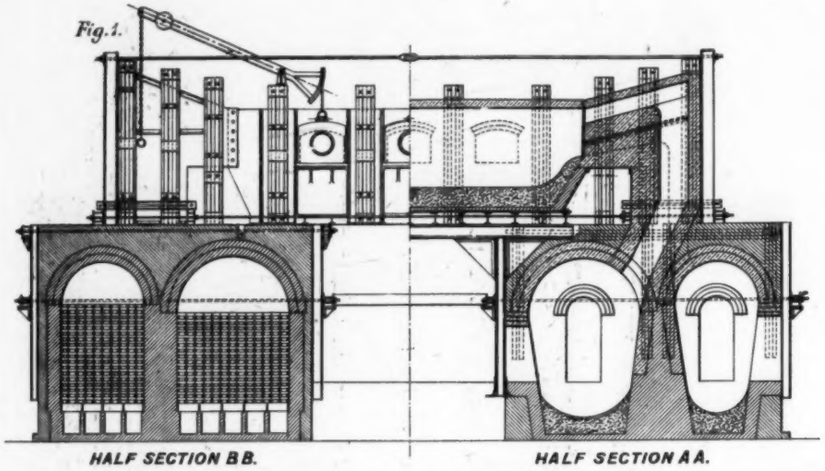
(*To face page 422.*)

GAS-FIRED STEEL MELTING FURNACES.

CONSTRUCTED BY MESSRS. G. P. WINCOTT, LIMITED, SHEFFIELD.

(*For Description, see Page* 422.)

Fig. 1.



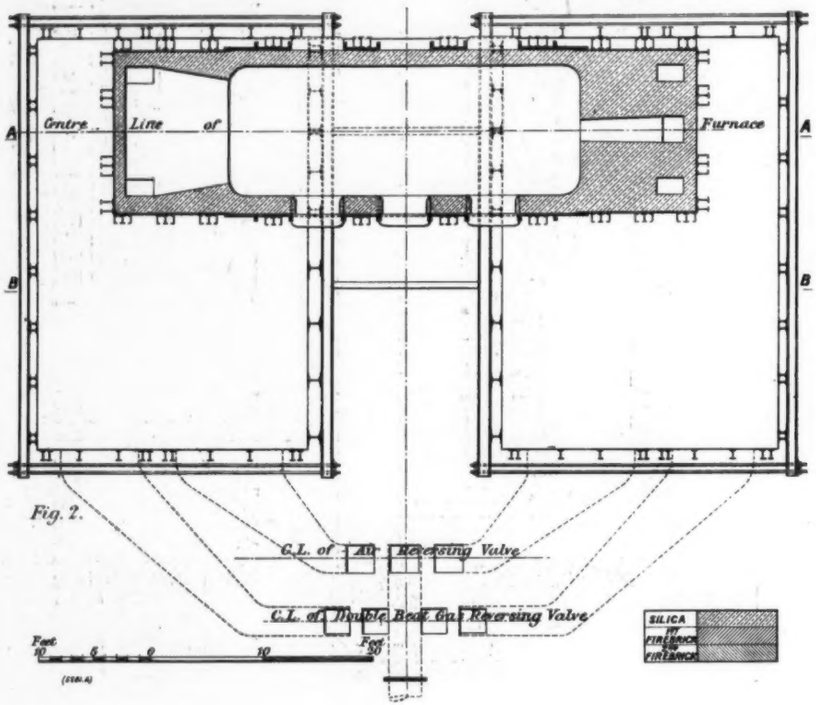


Fig. 2.

FIG. 3.

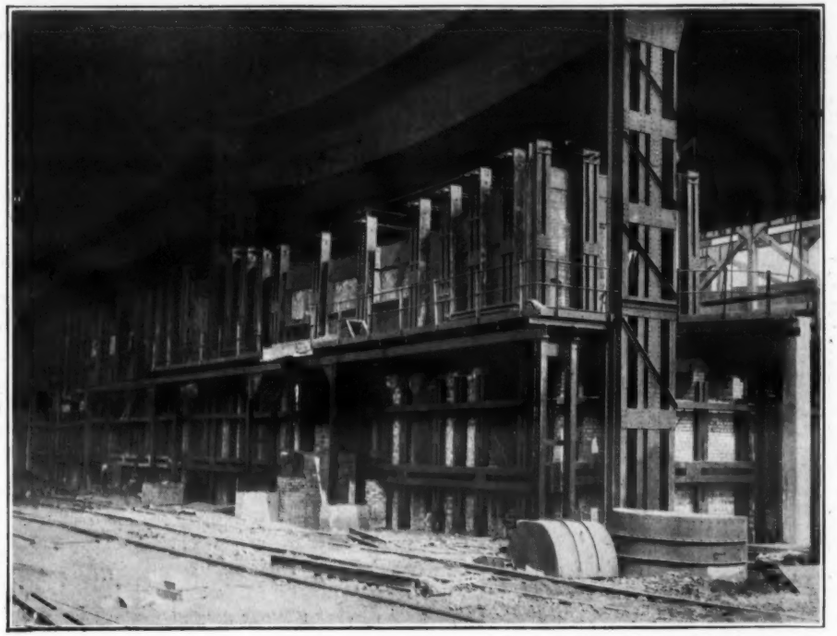


FIG. 4.

FORGE FURNACES AND SHELL HEATING FURNACE.

CONSTRUCTED BY MESSRS. G. P. WINCOTT, LIMITED, SHEFFIELD.

(*For Description, see Page 422.*)

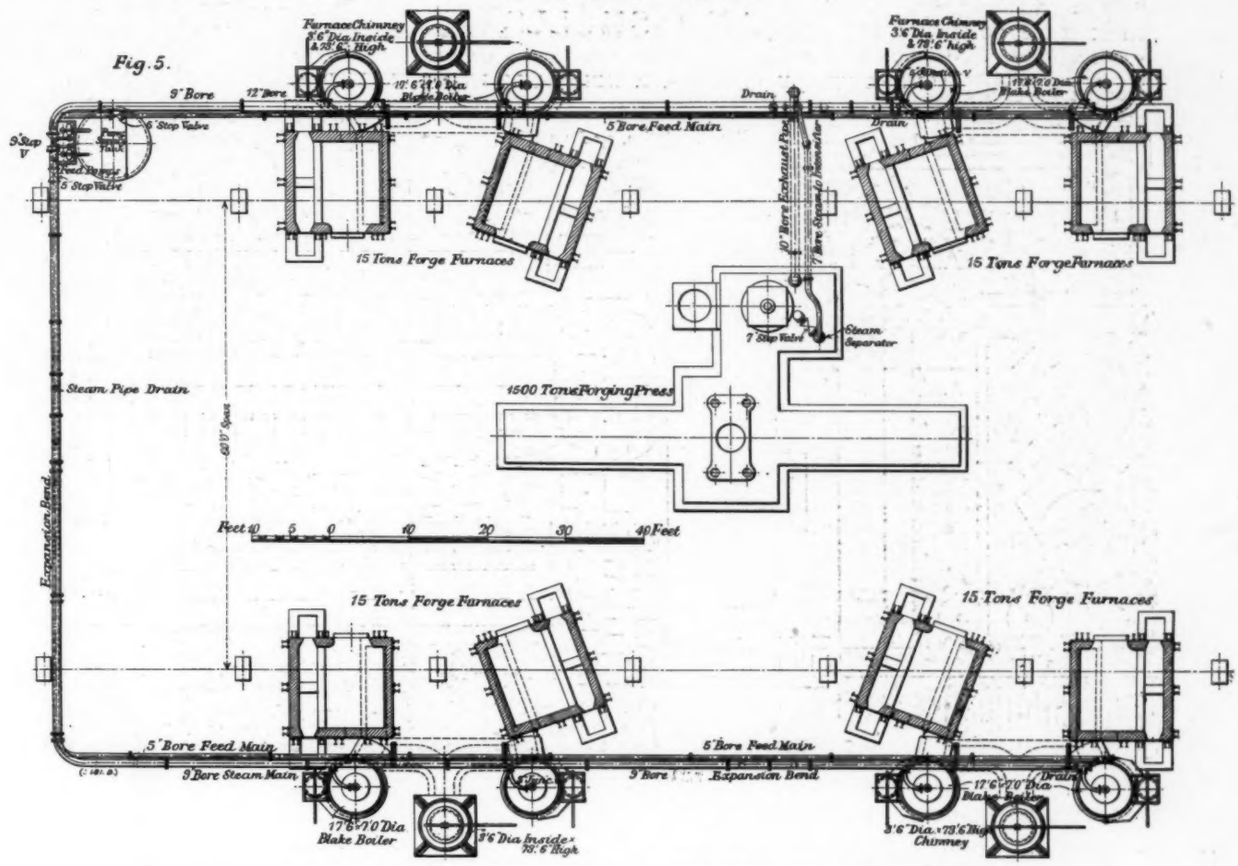
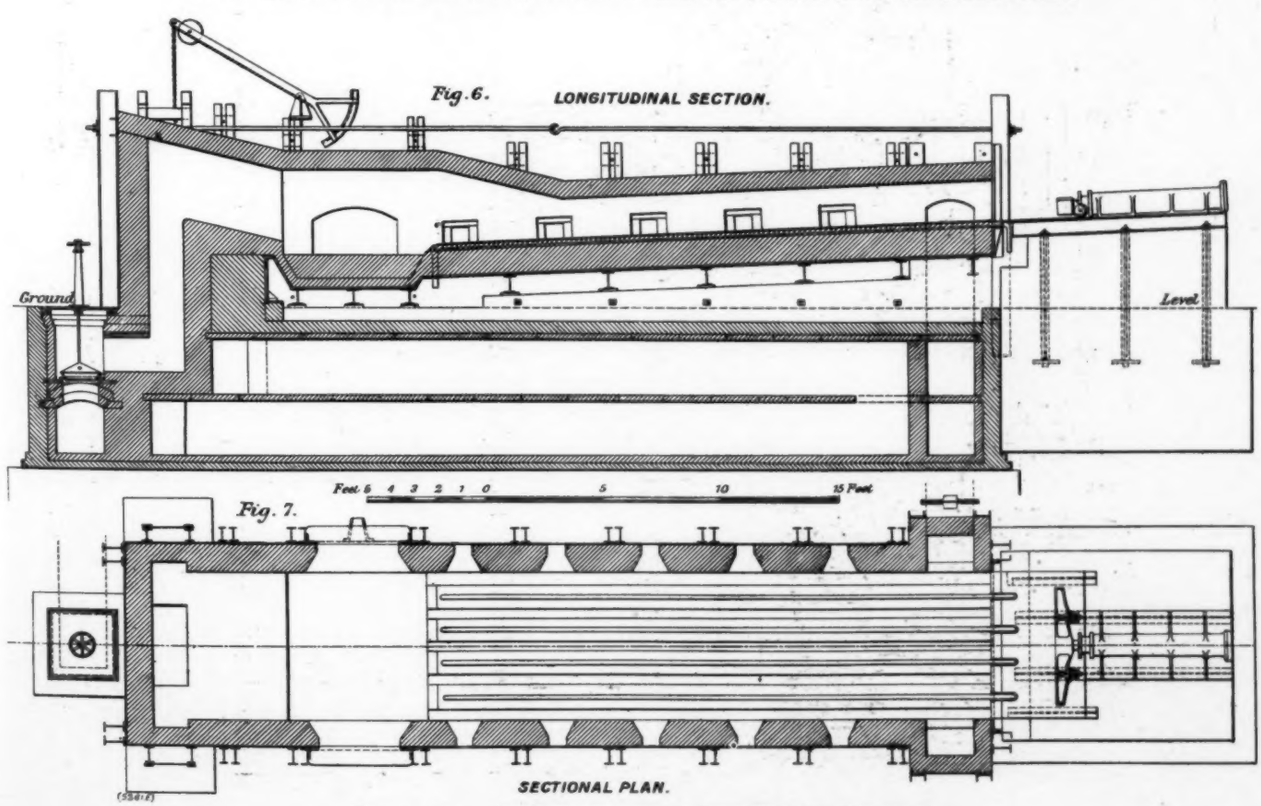


FIG. 5. LAY-OUT OF FURNACES AND WASTE HEAT BOILERS FOR USE WITH A 1500-TON FORGING PRESS.



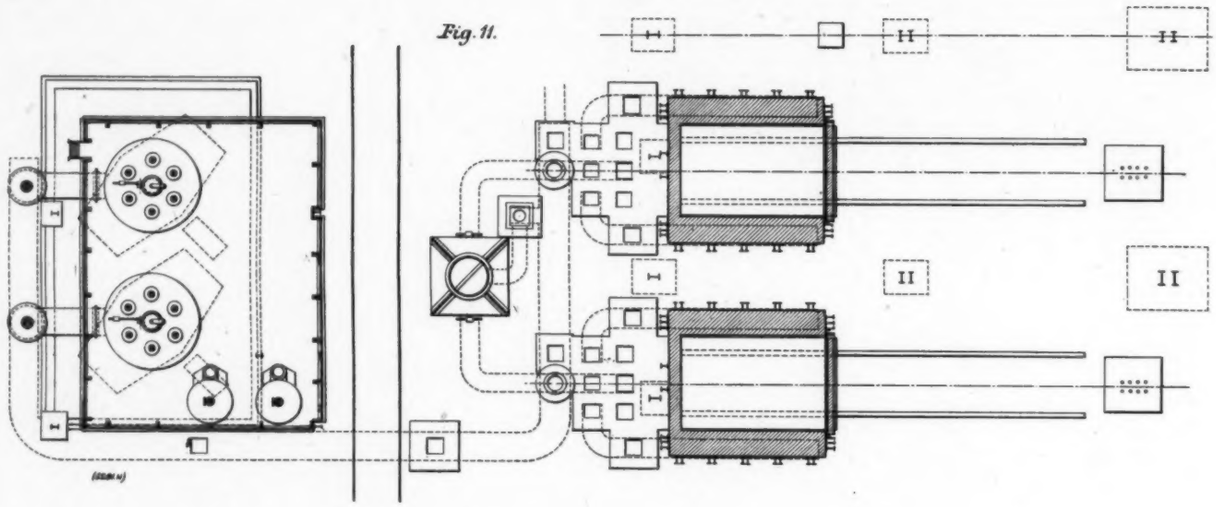
FIGS. 6 AND 7. GAS-FIRED CONTINUOUS SHELL HEATING FURNACE.

FURNACES FOR ANNEALING LARGE STEEL CASTINGS AND SHELLS.

CONSTRUCTED BY MESSRS. G. P. WINCOTT, LIMITED, SHEFFIELD.

(*For Description, see Page 422.*)

Fig. 11.



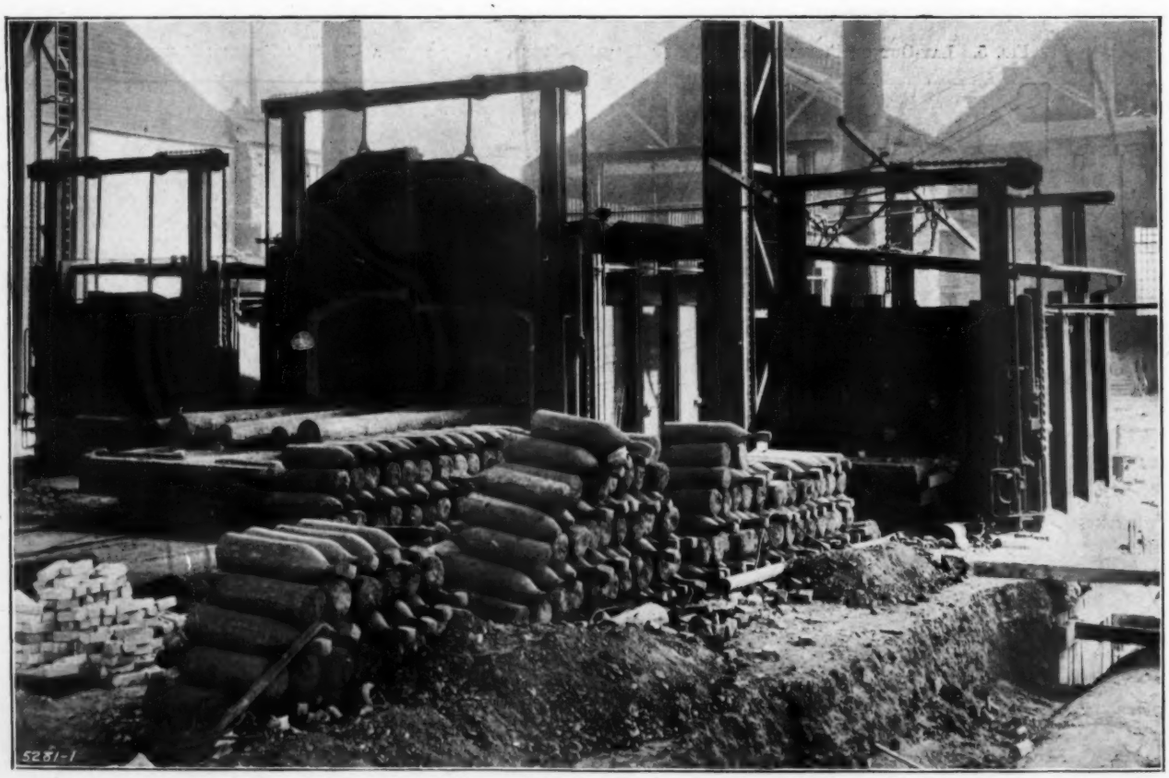


Fig. 12.

(*To face page 423.*)

FURNACES FOR HEATING BILLETS AND SHELLS.

CONSTRUCTED BY MESSRS. G. P. WINCOTT, LIMITED, SHEFFIELD.

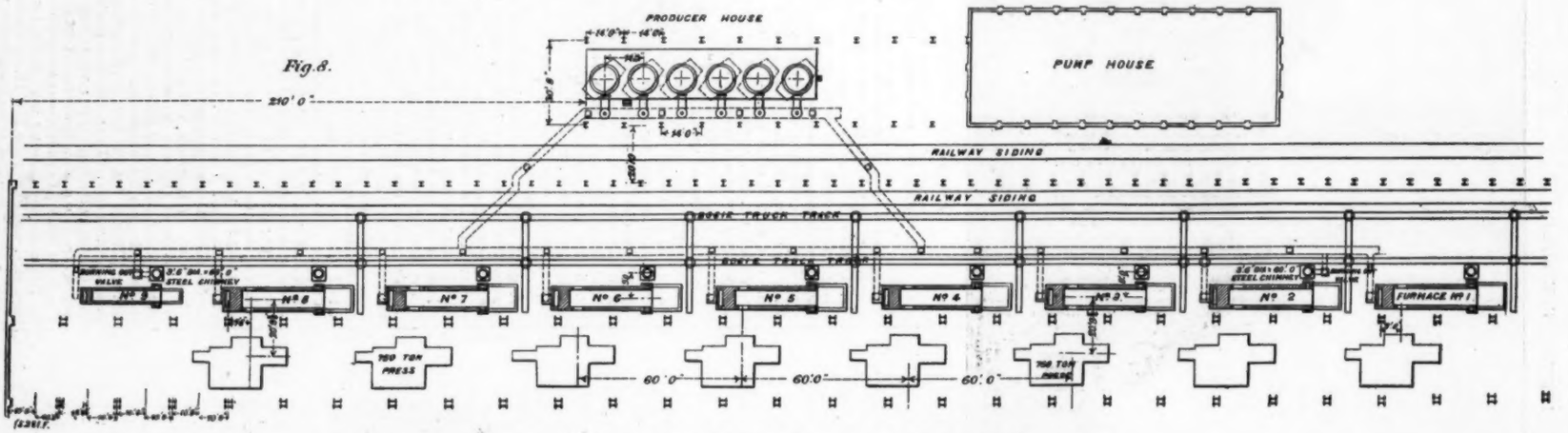
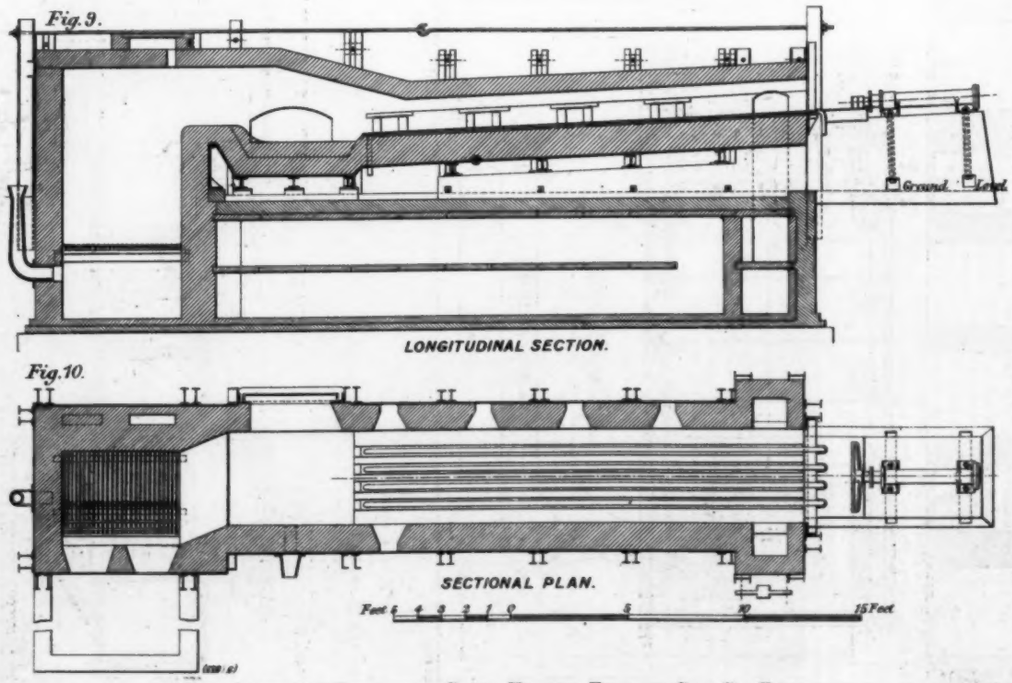


FIG. 8. LAY-OUT OF NINE GAS-FIRED CONTINUOUS SHELL HEATING FURNACES.

this country. The firm has had large experience in the construction of furnaces of all types and also in their maintenance, they being now one of the leading firms of furnace constructors connected with the special trades of steel melting and the heat-treatment of steels.

It is not possible in the space available, nor is it necessary, to describe all the types of furnaces built by Messrs. Wincott, but it may be noted that their experience is not confined to steel furnaces only, but that the firm have a trained staff for dealing with other special furnaces, such, for instance, as those required for glass manufacture. The following particulars and the illustrations of furnaces actually installed by Messrs. Wincott and in regular service, which we publish in the present issue, indicate that the designs are robust and that the details are simple, these being very important points which are too often overlooked or neglected. It will be noted from the illustrations that the firm construct furnaces in which the firing is effected by means of producer gas, semi-gas or solid fuel, but in designing the plants they prefer where large plants are being worked, to install gas-fired furnaces. The advantages of this system of firing are well known, but it may be useful to briefly state that they are: reduced consumption of fuel, the heat required can be obtained and maintained for any period within practical limits, and the retention of an even and definite temperature which is under the control of the operator. Producer plants are generally placed outside the furnace shop and being centralised the cost of dealing with the coal and ashes is reduced; further, the smoke nuisance can be dealt with much more effectively than in direct fired furnaces, in fact it should be eliminated.



FIGS. 9 AND 10. CONTINUOUS SHELL HEATING FURNACE, SEMI-GAS-FIRED.

There are cases, however, where the introduction of the gas fired furnace is not justified either on account of the class of work to be performed or the size of the installation; in such cases, if the circumstances indicate that such a course is justified, furnaces can be supplied fired on either the semi-gas or solid fuel systems. The question as to which type of furnace is the better for a given service is a matter of experience in design, knowledge of local conditions and the balancing up of the requirements for a given service.

From the particulars of furnaces which Messrs. Wincott have placed at our disposal we have selected the following typical examples, and we have had an opportunity of seeing some of the furnaces at work.

The steel melting furnace shown by Figs. 1 and 2, Plate XLII, is for the production of mild steel by the acid process and has a capacity of 50 tons. Over 20 furnaces of this type have been installed and others are in course of erection, the combined capacity of all the furnaces being in the vicinity of 700,000 tons of steel per annum. The fuel consumption of the 50 ton furnace is given at $4\frac{1}{2}$ cwts. per ton of mild steel, when all is charged in cold, and is based on an output of over 27,000 tons per furnace year. This consumption is exceeded in the case of furnaces which are producing the high-carbon and special alloy steels; the figure may in such cases be in the vicinity of 8 cwts. per ton of steel produced.

Fig. 3 on the same plate shows the charging side of a 50-ton furnace under construction, while Fig. 4 gives a very good indication of the tapping side of the

RE-HEATING FURNACE AND GAS-PRODUCERS.

CONSTRUCTED BY MESSRS. G. P. WINCOTT, LIMITED, SHEFFIELD.

Fig. 13.

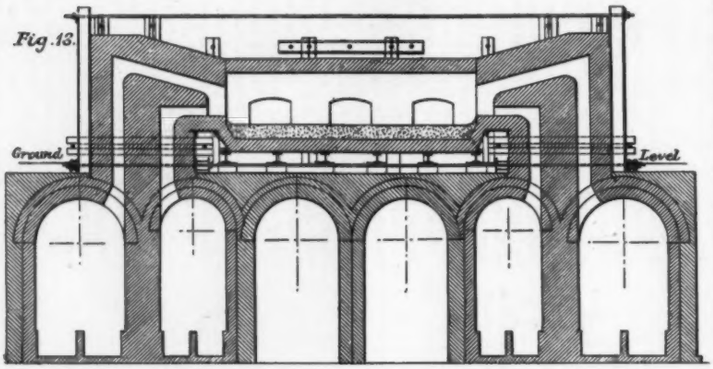
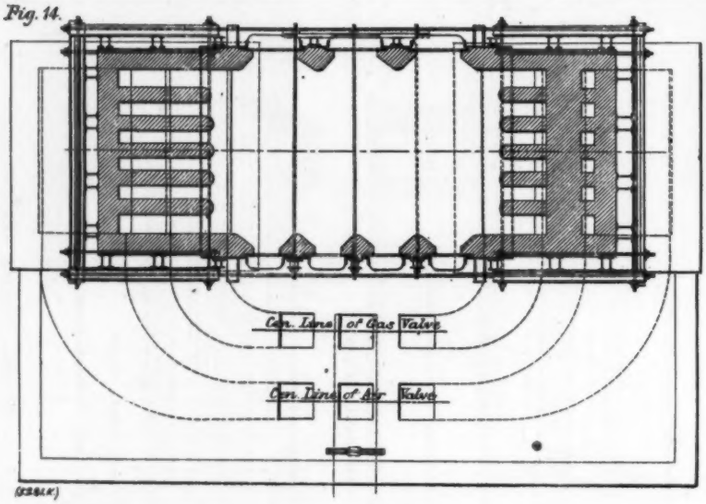


Fig. 14.



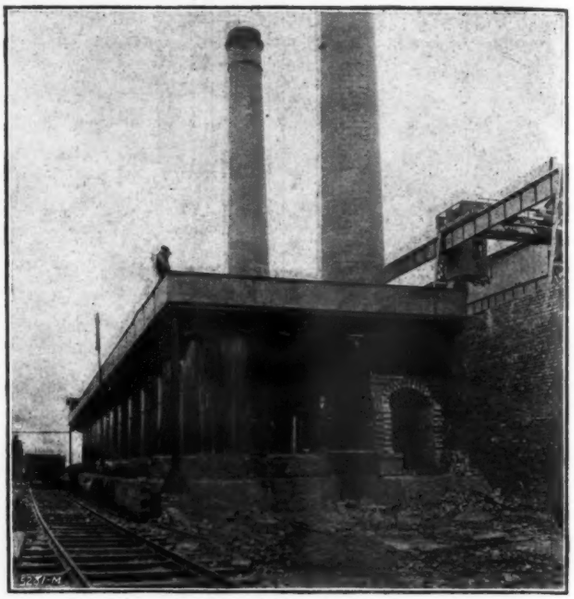
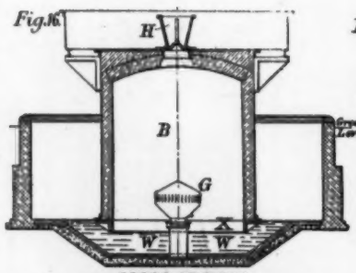


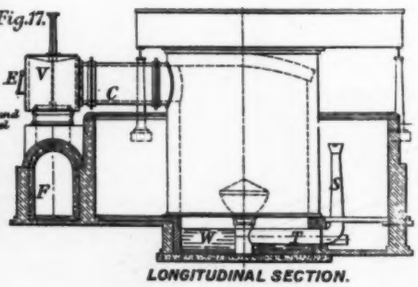
FIG. 15.

Fig. 16.



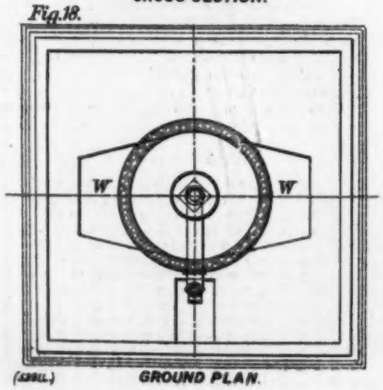
CROSS SECTION.

Fig. 17.



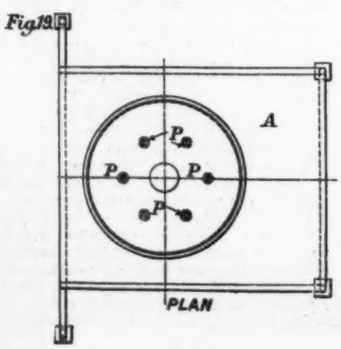
LONGITUDINAL SECTION.

Fig. 18.



GROUND PLAN.

Fig. 19.



PLAN

same furnace with the buck-stays and staging in position.

A modern lay-out of furnaces complete with waste-heat boilers for a 1,500 ton forging press is shown on Fig. 5, Plate XLIII. The furnaces are installed for a large output from one press and are arranged so that the withdrawal of the heated ingots from the furnaces may be carried out easily and with economy in crane operation. The furnaces are fired with solid fuel. One vertical Blake waste-heat boiler is installed for each furnace, these supplying all the steam required for operating the steam intensifier under advantageous and economical conditions. The fuel consumption for such an equipment with waste-heat boilers is stated to be about 26 cwts. per ton of finished forgings when working on solid shaft forgings, and ranging between 26 cwts. and 30 cwts. for hollow forgings and heavy forgings such as large rudder and propeller brackets. The whole scheme is compact and simple, and the output should be good. The arrangement shown in Fig. 5 has been designed by Messrs. Davy Bros., Limited, of Sheffield, the makers of the forging presses, in conjunction with Messrs. Wincott, Limited, the builders of the furnaces.

A great deal of attention is being given at the present time to the type details and layout of furnaces for the heating of billets and shells. Figs. 6 and 7, on Plate XLIII, show the Wincott gas-fired continuous shell heating furnace in which the floor of the furnace is inclined and the billets are gradually pushed down to the heating chamber on water-cooled skid pipes. By this method the billets are subjected to a soaking heat. Fig. 8, on page 423, shows the lay-out for nine such furnaces with gas producers, &c. A large number of these furnaces have been erected in the last two and a half years for shells ranging from the 18-pounder up to the 15 in., these furnaces having a combined capacity of well over 300,000 shells per week. With a lay-out such as this the solid fuel consumption averages from 12 per cent. to 15 per cent. by weight of the billets heated, these figures being based on the results of working for a period of six months under normal conditions. Figs. 9 and 10, on page 423, show a furnace for similar work, but of the semi-gas fired type.

There are of necessity a large number of designs for the various types of furnaces required to meet all the special and general services embraced under the headings of annealing, hardening, reheating, tempering, &c., and Messrs. Wincott have designs which cover all these requirements. These furnaces may be of the fixed bottom or the bogie type; when large and heavy forgings are to be dealt with the bogie type are installed. Fig. 11 on Plate XLIV illustrates an up-to-date lay-out for two annealing furnaces with bogies for annealing large steel castings, while Fig. 12, on the same plate, shows a larger gas-fired annealing furnace with bogie for the heat-treatment of forgings for guns, marine shafts, &c. Figs. 13 and 14, annexed, show the

type of furnace developed by the firm for reheating blooms and billets for rolling mills and tube works. This furnace is gas-fired and is also suitable for piling.

The firm are also the constructors of gas producers and Fig. 15 to 19, on page 424, illustrate examples. Fig. 15 shows part of a battery of 18 producers in course of erection. The Wincott producer is of the central blast water-bottom type, it is simple in construction and easy to maintain. It is made in five standard sizes, the capacities being 2½ cwts., 5 cwts., 7½ cwts., 10 cwts. and 12½ cwts. The main features of the design are shown clearly by Figs. 16 to 19. A considerable number of these producers have during recent years been erected in steel and other works.

INDUSTRIAL NOTES.

WE have received from the Publicity Department of the Ministry of National Service a copy of the new Order under the Military Service Act, 1918, Section 2, which cancels a large number of occupational exemptions from military service granted by tribunals.

Arrangements have been made by which a copy of the Order and Schedule may be inspected by those concerned at Employment Exchanges and National Service Offices, or purchased at bookstalls or through the usual Government channels. Price 1d.

The new Order in question is the one we referred to on page 407 *ante*.

A second ballot of the members of the Amalgamated Society of Engineers on the Government's proposals to take more men from the shops shows a substantial majority in favour of accepting them. The figures were :—

For accepting the Government's proposals and explanations	58,650
Against	46,332
Majority in favour	12,318

The first ballot taken last February showed a majority of 93,547 against the Government's comb-out. Further, by a majority of 22,392 (28,204 votes against 5,812), affiliation of the Amalgamated Society of Engineers to the Trade Union Congress has been agreed upon.

The Director of the Department of Labour Statistics, dealing with the labour market in *The Labour Gazette*, states that employment continued very good in March in most of the principal industries, and the iron and steel, shipbuilding and engineering trades were still working at great pressure. The restriction of consumption of raw materials, however, continued to affect employment in the textile industries, and in the cotton trade, especially, employment showed a decline.

Trade unions with a net membership of 1,068,154, excluding those serving with the forces, reported 12,397 (or 1·2 per cent.) of their members as unemployed at the end of March, compared with 0·9 per cent. at the end of February and 0·3 per cent. at the end of March, 1917. The increase in the percentage as compared with a month ago and a year ago was almost entirely due to the cotton industry, in which the "unemployment" is in the nature of short time—the operative affected not being discharged, but merely suspended in rotation for one week out of four or more according to circumstances.

Of the 3,662,673 male and female workpeople insured under the National Insurance Acts, 1911 to 1916, the number unemployed at the end of March was 36,873 (or 1·01 per cent.), compared with 0·89 per cent. in the previous month, and 0·66 per cent. a year ago. For males and females separately the percentages unemployed at the end of March were 0·41 and 2·36.

The average weekly number of vacancies notified to all Employment Exchanges for the four weeks ended March 8, 1918, was 40,720, as compared with 41,417 in the previous four weeks and with 44,608 in the four weeks ended March 9, 1917. The average weekly number of vacancies filled for the same period was 30,042, 31,876 and 35,824 respectively. The number of workpeople remaining on the live register at March 8, 1918, was 31,483 men, 56,377 women, 7,697 boys, and 8,093 girls, a total of 103,650.

The changes in rates of wages (including war bonuses) reported to the department as having been granted during March (including some increases awarded during that month to have effect from earlier dates in 1918) resulted in a net increase of over 67,000*l.* in the weekly wages of over 220,000 workpeople.

The principal bodies of workpeople affected were tramway and omnibus workers and aircraft workers. Employees in the traffic section of tramway and omnibus undertakings received war wage advances raising the wages of men, and of women paid at men's rates, to 20*s.* above pre-war rates, with smaller increases to other women, boys and girls. Skilled aircraft woodworkers were awarded an advance of 5*s.* per week, as war wages, and bonuses on earnings of 12½ per cent. to men on time rates and 7½ per cent. to men on piece rates. The bonuses of 12½ per cent. and 7½ per cent. were also extended to men in various metal industries and in a number of local authority undertakings.

The number of disputes beginning in March was 83, and the total number of workpeople involved in all disputes in progress was 46,900, as compared with 55,800 in the previous month, and 28,900 in March, 1917. The estimated total aggregate duration of all disputes during the month was 276,200 days, as compared with 287,500 days in February, 1918, and 202,000 days in March, 1917.

When presiding at the sixth ordinary general meeting of Messrs. Lamport and Holt, Limited, held in London on the 11th inst., Sir Owen Philipps, K.C.M.G., M.P., the chairman, said it had been suggested that, after the war, British shipping should be nationalised and become a State industry or monopoly. Such a course would, he felt convinced, lead to the certain loss of our maritime supremacy, which, as an island people, was a vital necessity, if we were to continue to hold the place in the world which we had held in the past. Whilst the nation might possibly with advantage (though, even here, opinions naturally differed) nationalise railways, gas, electricity, and similar public services, because they were internal and the Government could easily protect them from outside interference and competition, the sea was, and always would be, open to all the world—so that shipping was in a very different position, and was the very last thing to which the principle of State ownership could be safely applied. This country, hitherto, had been the great ocean carrier of the world, transporting produce and manufactures cheaply, not only to and from our own shores, but also between one foreign country and another. This position had enabled us in war time to provide the British Navy with an immense and powerful auxiliary, and to bring overseas troops, munitions, foodstuffs, &c.

One thing was certain, and that was that after the war foreign competition would be keener than ever before—neutrals especially had huge sums in reserve wherewith to build new fleets or to enlarge existing ones; whilst we knew that Germany was making preparations on an immense scale to contest our maritime supremacy after the war. The Bill for the Restoration of the German Mercantile Marine, which passed through the Reichstag last November, provided for money grants to shipowners for the construction of new tonnage amounting, on the most moderate computation, to 50,000,000*l.* In reply to a suggestion then made that shipping should be nationalised, the German Government stated that "nothing was less suited than shipping to form a Government monopoly, and that the effect of a Government monopoly would be to threaten German trade with the loss of the international possibilities of expansion upon which its greatness had been based." Sir Owen therefore anticipated for the British mercantile marine a very acute struggle if it was to hold its own. Could the nation, under such circumstances, look with confidence to doing so if our shipping was to be taken over and administered by a Government Department? He, personally, held a high opinion of British civil servants, but was any Government Department likely to provide for, build up and maintain, in good years and bad years, often at heavy loss year after year, such services as Lamport and Holt had fought for and held? He did not consider it probable or even possible. The war had shown the country that many good business men made very second-rate officials, whilst the training of our Civil Service, which service was, he believed, the best in the world, was not the best school for a business man.

"Our scheme of 'Closer Unity' with the shipwrights has now been extended to include the blacksmiths," says the report for April of the United Society of Boilermakers and Iron and Steel Shipbuilders. "The members and officials of the three unions will now act together on all general trade questions. This, in itself, is a big step forward, but all of us are pledged to take the voice of our members by a ballot vote on the question of complete amalgamation of the three societies. This vote is to be completed within twelve months from February last, so that before the close of the present year the amalgamation proposals will be in the hands of the joint members. We look to our members who have advocated the more ambitious proposal of 'one industry, one union,' and hope they will continue their propaganda in the coming months to secure the unification of three important societies in the shipbuilding and engineering industry."

The membership of the society is now 82,000.

Speaking at a luncheon given on Wednesday, the 10th inst., by Messrs. Whitehead's Aircraft, Limited, Mr. G. H. Roberts, Minister of Labour, said he thought we might accept it that we could never go back to the pre-war conditions with the old type of employers who held that they should be perfectly free to buy labour as they would an ordinary commodity. On the other hand, he was strongly opposed to those who would seek to delude labour into the belief that it was but necessary to demand the utmost regardless of the return they were prepared to render for it, and therefore he was concerned in bringing the two parties together. The department over which he presided for the time being was charged, he added, with some of the heaviest responsibility connected with the whole future destiny of the country. For if the war gave place to industrial strife, all planning and all wise schemes would count for nought, and that gave evidence of the imperative necessity for a proper reconciliation of workpeople and employers. The Government foresaw that this problem would have to be dealt with and appointed a committee; this committee consisted of men representing all phases of modern thought, and yet they succeeded in arriving at unanimous conclusions. There were extreme labour men on the one hand and the old-fashioned employer on the other, but when confronted with the absolute necessities of the case, the spirit of compromise operated. One moved forward a little, and the other came back to meet his friend, and they had presented certain recommendations upon the successful adoption of which, he believed, rested the whole future of the country. Joint Industrial Councils were being established in every industry. These councils would be permanent in character, and it was felt already that something had been lost in not keeping bodies comparable to these for use during the war. For much of the control which had been complained of would have been unnecessary if there had existed in every industry councils equally representative of employers and employed, competent to speak in an authoritative voice on behalf of the particular industry concerned. The control which to-day was irritating was entirely attributable to the fact that the employer and workpeople had not the perspicacity to see that some occasion might arise when it was necessary to have these bodies to advise the Government on behalf of industry.

There were many workpeople who thought that orders flowed into works just the same as rain fell from heaven. They had no knowledge whatever of the difficulties of an employer, and the employer had to initiate them into his needs and when that was done the employer could develop within them a sense of responsibility which would reflect itself in better and more reasoned men as the years passed on.

Workpeople and employers, Mr. Roberts concluded, must act in co-operation. Each must do their best for each other, not only because of the individual advantage which will accrue, but as recognising that they are both the custodians of the State as a whole.

On Saturday last, the Minister of Pensions, Mr. John Hodge, addressed a meeting at Hanley of the North Staffordshire branches of the Iron and Steel Trades Confederation. He said that the confederation was due to the Kaiser; before the war, the various trade unions fought against one another, but they recognised their folly in the greater fight that was taking place. The very fact that the unions had been drawn together would make the work of reconstruction, when it came, much easier. When peace came, the problem of finding work for demobilised men would be a trying task, but by the reduction of hours in the iron and steel trades to eight a day, they would absorb 100,000 men. Mr. Hodge added that some Labour Party members said that men like himself, who talked about not giving an open door to the Germans when peace was declared, were seeking to perpetuate an economic war. "We do not want to do anything of the kind," Mr. Hodge stated, "but what we ask, is how, after the brutalities of the Germans, after their dastardly acts and brutal murders, can we permit them to come into this country with their goods after the war as they did before it?" He was not willing, as a steel worker, and the members he addressed were not willing, as iron and steel workers, to have furnaces idle in this country while German steel was being dumped into it. There must be none of that.

THE LATE MR. ANDREW M'ONIE, GLASGOW.—We regret to learn of the death, at 3, University-gardens, Glasgow, on the 12th inst., of Mr. Andrew M'Onie, who belonged to a family of engineers who did much to develop and maintain the prestige of the West of Scotland for general engineering, and particularly sugar plant. At the same time they were closely associated with the corporate life of Glasgow, his father, Mr. Andrew M'Onie, having been deacon convener, and his uncle, the late Sir William M'Onie, having been Lord Provost of Glasgow. The firm with which the deceased was latterly identified was Messrs. A. and T. W. M'Onie, with works at Govan, which were acquired by the firm of Messrs. McKie and Baxter in 1917, at which time the deceased retired from business. He was 59 years of age, and is survived by his wife.

THE IRON CARBON EQUILIBRIUM DIAGRAM AND ITS PRACTICAL USEFULNESS.*

By Professor H. C. H. CARPENTER, M.A., A.R.S.M., M.I.M.M. (Royal School of Mines).

(*Continued from page* 395.)

The next step is to describe briefly the interpretation of the various areas in the diagram, to enumerate the constituents present in each, and to demonstrate the changes that occur when a boundary line is crossed. After this the changes undergone by pure iron and four steels of great industrial importance, both on cooling from the melt and reheating to it, will be considered.

(1) The Liquidus. Line A C, Fig. 7, page 394 *ante*.—This is a smooth curve slightly convex upwards, and drops from 1,505 deg. C., the freezing-point of carbonless iron, to about 1,140 deg. C. at 4·3 per cent. of carbon. There is thus a total fall of no less than 365 deg. The curve may be represented by the equation—

$$T = 1{,}505 - 54{\cdot}65\,C. - 7{\cdot}1\,C^2,$$

where T is the temperature in degrees Centigrade and C the percentage of carbon. From this curve the following short table has been calculated.

Percentage of Carbon.	Beginning of Solidification. Deg. C.
0	1,505
1	1,444
2	1,368
3	1,278
4	1,173
4·3	1,139

(2) The Solidus. Line A E C.—As explained, some uncertainty exists with regard to the exact slope of A E. E C, however, is fixed. The constituents present in the area A E C consist of liquid and a solid solution of carbon in γ iron known as austenite. The solubility of the carbon at 1,140 deg. C. is about 1·8 per cent. Along A E one constituent separates—the austenite just referred to, whose composition varies from 0 per cent. to 1·8 per cent. Along E C two constituents separate, viz., austenite with 1·8 per cent. of carbon and cementite (iron carbide) with 6·66 per cent. of carbon. As these two phases are in equilibrium with the melt, we have an invariant system with no degrees of freedom, and the line E C D must be horizontal. The point C is situated at 4·3 per cent. of carbon, and is called the eutectic, *i.e.*, the lowest melting alloy of the series. B C is the line of separation of cementite from the melt, and along C D (the solidus) austenite and cementite are deposited, the amount of the latter steadily increasing with the percentage of carbon. (Although it is probable that under certain conditions free carbon in the form of graphite or "kish" can separate along the line F G, giving rise to another eutectic, viz., graphite and austenite, this is one of the points in regard to which uncertainty still exists.)

(3) The area A G O S E.—Here, one phase only is present, viz., austenite. It is terminated as regards the lower part by two descending curves. Along G O S, iron separates, along S E cementite is deposited. It is very difficult to retain the structure of austenite even by rapid chilling owing to its extreme tendency to split up into ferrite and cementite, and the fact that its structure is altered by the stresses set up on quenching from a high temperature. With high carbon alloys, however, containing some manganese the true austenitic structure can be obtained. A typical structure is shown in photograph No. 1, page 430, and is seen to consist of irregularly outlined polygonal crystals characteristic of a solid solution. These crystals show a great tendency to "twin." The low carbon alloys in this area when quenched give rise to an acicular structure which masks the polygonal and homogeneous character of the crystals. This is shown in photograph No. 7, page 430, and is called martensite.

(4) The area G M O contains austenite and β iron, while the (5) area M O S L contains α iron and austenite. The temperature at which β iron deposits from the solid solution depends on the carbon concentration, whereas α iron separates along the line M O, which is approximately horizontal. On the other hand, from O to S α iron is deposited at temperatures which fall as the carbon concentration is increased.

(6) The large area E S K D contains the two phases austenite and cementite. The solubility of carbon in austenite diminishes as the temperature falls from 1,140 deg. to 725 deg. C., and whereas it is about 1·8 per cent. at the former temperature it is only about 0·9 per cent. at the latter temperature. Along the line E S therefore cementite crystallises and at S itself austenite has been narrowed to this particular composition. At this point it splits up on cooling into the two phases, a ferrite and cementite or iron carbide, and below the line L S K these two phases exist. At this line three phases are in equilibrium—austenite, ferrite and cementite. The system has therefore no degrees of freedom and the line must be horizontal. S is called the eutectoid point. The ferrite and cementite are usually deposited in characteristic alternate plates with a laminated appearance and are called pearlite from their analogous appearance to mother-of-pearl. This matter was fully dealt with by Professor Dalby in his paper and does not require to be further elaborated. An example is, however, to be seen in photograph No. 9, page 430. So far as we know this is the last structural change undergone by the alloys on cooling, so that all steels in equilibrium at the ordinary temperature consist of mixtures of α iron or ferrite and cementite or iron carbide, the exact proportion in any given case depending on the concentration of carbon. The proportion can be seen at a glance in Fig. 8. The pearlite itself consists of about 86·5 per cent. of iron plates and 13·5 per cent. of cementite plates—on the assumption that no carbon is dissolved in the iron. This may not be quite true, but the amount dissolving is very small.

Let us now consider what takes place when certain typical steels are cooled from the liquid condition.

(*a*) *Pure Iron.*—Although this is not a commercial alloy, it is convenient to begin with it, as the first member. In one sense this material is unique in the series, in that it freezes at one temperature, whereas the remaining members with one exception freeze over a range of temperatures. Put rather differently, pure iron has a freezing point, whereas all steels have a freezing range. This is not only a scientific distinction but is accompanied by important practical consequences. Pure iron freezes at just above 1,500 deg. C.—to be exact, about 1,500 deg. to 1,510 deg. C. This is γ iron. It then cools for about 600 deg., before the next change happens, which is the conversion of γ to β iron at about 900 deg. C. This accordingly is the second heat evolution on cooling. The third and last heat evolution occurs at about 765 deg. C., but, as already explained, this is spread over an interval of temperature, when α iron is produced. This, in contradistinction to both γ and β, is magnetic, and is the form stable at the ordinary temperatures.

The main differences in the properties in these three forms of iron are as follow: γ iron can dissolve considerable quantities of carbon, and is non-magnetic. The solubility of carbon in β iron is probably very slight; this variety is also non-magnetic; α iron can dissolve only very small amounts of carbon and is magnetic. Between γ iron on the one hand, and β and α on the other, there are well-marked crystallographic differences, but so far as is known no difference exists between the crystalline forms of β and α iron. The structure of a very pure sample of α iron, containing only four parts of impurity in 10,000, is shown in photograph No. 2, page 430. The remarkable feature of this photograph is the large size of the crystals and the extraordinary fineness of their boundaries. This photograph may be compared with that of γ iron (austenite), already mentioned, where the boundaries are much thicker (No. 1, page 430). The four succeeding alloys will be discussed, even though they are industrial alloys, as though they contained nothing but iron and carbon. Strictly speaking, certain other elements which are present, *e.g.*, silicon, manganese, sulphur and phosphorus, should be taken into consideration. The only difference, however, that they would make would be to alter somewhat the temperatures at which the heat evolutions and changes of structure occur. They do not alter the essential character of the cooling phenomena, and may therefore be legitimately omitted for the purposes of this paper.

Fig. 8.

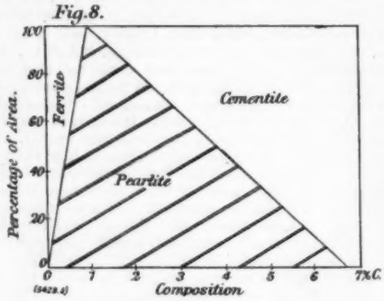


Fig. 9. (AFTER HOWE).

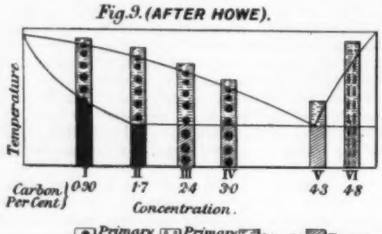
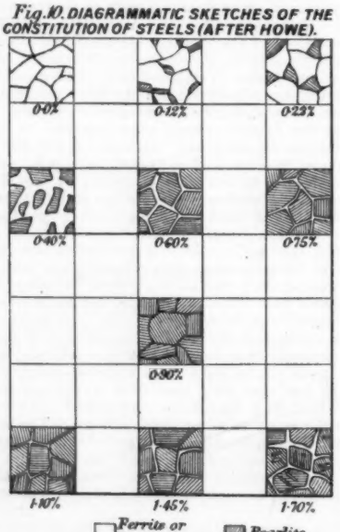


Fig. 10. DIAGRAMMATIC SKETCHES OF THE CONSTITUTION OF STEELS (AFTER HOWE).



(*b*) *Mild Steel.*—This alloy has an extraordinary wide use in naval architecture, and deserves the closest consideration. Let us take a steel with about 0·2 per cent. carbon. Reading from the equilibrium diagram, it will be seen that it begins to freeze at about 1,495 deg. C., and that the freezing continues until about 1,450 deg. C., that is, the freezing range is about 45 deg. C. We must note here what happens. At the point on the liquidus curve A C, where the first crystals separate, they do not contain the same amount of carbon as the liquid; they contain less, and the exact amount is given by drawing a horizontal from this point on the liquidus to the solidus curve A E. The point where the latter is cut gives the percentage of carbon in the austenite. The effect of this, of course, will be to enrich the liquid in carbon and accordingly the composition of the liquid shifts to the right. As a result, the next crystals which separate, while poorer in carbon than the liquid, are richer in carbon than the first crystals deposited. This in its turn effects a further enrichment of carbon in the liquid, and so the changes go on during the freezing range, each successive layer of austenite being richer in carbon than the previous one. Accordingly—and this is the important point—the austenite deposited is by no means homogeneous corresponding at any point to the mean composition 0·2 per cent. carbon, but is built up of layers both poorer and richer than this mean figure. The alloy then cools through about 600 deg. C., and unless the cooling is very rapid, these differences in composition tend to equalise themselves by diffusion.

At about 890 deg. C. the austenite begins to deposit β iron; this, as already explained, is nearly, if not quite free from carbon; therefore, by this process, the austenite is enriched in carbon, and the composition moves down the line G O S. β iron continues to crystallise as the temperature falls, until at 765 deg. C. it changes to α iron. From here down to about 700 deg. C. α iron is deposited, the composition of the austenite being steadily enriched in carbon, until, at this latter temperature, we have α iron and austenite, containing now no less than 0·9 per cent. carbon. Below this temperature the austenite splits up into α iron and cementite (pearlite); and the precise form in which the pearlite is obtained will depend on the rate of cooling through this change-point. The net structural result is, a steel composed predominantly of α iron having distributed through it small islets of pearlite.

The heating of such a steel follows the reverse course. Beginning at the ordinary temperature, no change other than a possible slight growth of the crystals and possible alterations in the distribution of the pearlite—to which reference will be made later—takes place, up to about 729 deg. C. At this point the pearlite is transformed into austenite. Passing upwards, the austenite begins to dissolve α iron, and the composition moves along the line S O G. At 765 deg. C. the α iron that is left is converted into β, and this in its turn is dissolved, until, at about 900 deg C., nothing but austenite is left, corresponding in composition to the mean figure 0·2 per cent. carbon. Proceeding upwards, the austenite tends to become homogeneous by diffusion, and at 1,450 deg. C. begins to melt. The composition of the liquid is not the same as that of the crystals, but is richer in carbon, and this continues in the reverse fashion to the phenomena described on freezing. It will be seen, therefore, that every piece of mild steel which is cast gives rise to no less than four heat evolutions on cooling, each of which is associated with a change of structure, and it will be obvious, therefore, that its properties must depend markedly on the rate at which the alloy cools through these change-points, because this affects the structure. Particularly does this apply to such steels as may be kept for a long time at temperatures which are not excessively high but are high enough for crystallographic changes to manifest themselves. More of this anon.

(*c*) *Medium Hard Steel.* Carbon 0·50 per cent.—This corresponds very nearly to rail steel. In this case the alloy begins to freeze at about 1,478 deg. C. and continues to deposit crystals down to about 1,400 deg. C. It has, therefore, a freezing range of nearly 80 deg. C. Phenomena occur similar to those already described for mild steel, with this important difference, however—that, owing to the wider freezing range, layers of austenite of more widely differing composition are produced, and the effect of the higher percentage of carbon is to diminish the rate at which equalisation of composition by diffusion occurs. Proceeding downwards, and assuming that homogeneity is reached, the steel begins to deposit iron, at a point just to the right of O, and in this case it is α iron which is deposited direct from the austenite and not β, as in the previous case. From here onwards α iron continues to crystallise, and at 700 deg. C. the austenite inverts to pearlite. Obviously in this case the proportion of what may be called pro-eutectoid ferrite—that is, of iron which crystallises

* Paper read at the Spring meetings of the fifty-ninth session of the Institute of Naval Architects, March 21, 1918.

above the eutectoid point—will be smaller than in the case of the mild steel. Here, again, the precise form in which the ferrite and pearlite ultimately take shape in the steel depends on the rate of cooling. In the case of this alloy, therefore, there are three heat evolutions on cooling and, of course, three absorptions on heating.

(*d*) *Hard Steel.* Carbon 0·90 per cent.—This is a somewhat simpler case than the preceding ones. The steel begins to freeze at about 1,445 deg. C. It has a freezing range of probably not less than 120 deg. C. Even greater differences, therefore, of composition will be present in the steel, when it has just solidified completely; and a considerably longer time will be necessary to produce homogeneity by diffusion. On cooling further, only one more change takes place; the steel being exactly of the eutectoid composition, neither ferrite nor cementite is deposited, and at 700 deg. C. the entire mass inverts and forms pearlite. We have then a pure pearlite steel, the material which Professor Dalby has found, in what may be called its normal condition, to have an ultimate stress of 62 tons per square inch, against 16 tons for pure iron. This steel, therefore, has only two evolutions of heat on cooling, and from this point of view is the simplest of all the steels.

TEMPERATURES OF FREEZING AND TRANSFORMATION RANGES OF STEELS OBTAINED BY MEANS OF THE EQUILIBRIUM DIAGRAM.

Carbon, Per Cent.	Freezing Range.		A3 Change, γ to β iron, Deg. C.	A2 Change, β to α iron, Deg. C.	A1 Change, Austenite to Pearlite. Deg. C.	Separation of Pro-eutectoid Cementite. Deg. C.
	Beginning, Deg. C.	End, Deg. C.				
0·01	1,505	1,505	900	768	Not detected	—
0·1	1,500	1,475	875	768	725	—
0·2	1,495	1,449	850	768	725	—
0·3	1,487	1,432	831	768	725	—
0·4	1,479	1,414	812	768	725	—
0·5	1,470	1,404	Merged	768	725	—
0·6	1,463	1,394	Merged	768	725	—
0·8	1,450	1,350	Merged	730	725	—
0·9	1,443	1,332	Merged	—	725	—
1·1	1,434	1,310	—	—	725	810
1·3	1,426	1,286	—	—	725	890
1·5	1,406	1,244	—	—	725	930
1·8	1,383	1,179	—	—	725	1,000

(*e*) *Tool Steel.* Carbon about 1·25 per cent.—Freezing in this case begins at about 1,430 deg. C. and continues to about 1,290 deg. C.; the freezing interval therefore is about 140 deg. C. Even wider differences in composition than in the last case will exist in the alloy just after solidification, and in determining this part of the diagram, it is of the utmost importance to ensure that full opportunity is given for the attainment of homogeneity at the temperature in question. In this case, on cooling, the austenite ultimately reaches a point on the branch of the curve S E, which can be judged by erecting a perpendicular from the concentration base, and at this point free or pro-eutectoid cementite is deposited. On further cooling, deposition of cementite continues, and the composition of the austenite moves towards S; when the line L S K is reached the austenite is split up into pearlite as in the other cases. The final result, therefore, in this case is cementite and pearlite, and in producing this three heat evolutions have occurred.

These examples, photographic illustrations of which will be found in the paper, sufficiently describe the various changes of energy, composition, and structure that occur in some typical steels. They could, of course, be multiplied, but no new feature would be introduced. It will be seen, therefore, that so far as the equilibrium diagram is concerned, and neglecting the special constituents which may be caused by the presence of elements other than iron and carbon, the entire range of irons and steels (mild, medium, and hard) is expressible below the solidus in terms of four constituents: (1) γ iron (austenite), containing from 0 per cent. to 1·8 per cent. carbon; (2) β iron; (3) α iron (both of these latter carbonless, or almost so); and (4) cementite. According to our present knowledge, no other constituents find a place in the diagram. We must, however, not take into consideration certain well-defined structural entities in steels which may be and are produced under definite conditions, but not those of equilibrium. These new forms are produced during the change which occurs when austenite is converted into pearlite.

Hitherto we have been considering only the two extreme cases: either the austenite has been chilled so rapidly that the inversion to pearlite has been prevented, in which case, of course, austenite remains, or it has been cooled at such a rate that the normal results of the inversion at 700 deg. C. are visible in the form of well-defined plates or granules of ferrite and cementite. If, however, while avoiding severe quenching, the austenite is cooled so that, although the thermal evolution takes place, the structural constituents do not have time to separate in the well-defined form of pearlite, quite definite and typical structures are obtained which are associated with equally definite properties. Just short of pearlite, we have what is known as sorbite, in which there is no trace of laminated structure but only an indefinite granulation. Rather more rapid chilling produces the so-called troostite, which is of a dark, almost black, appearance; both of these, however, are, from the constitutional point of view, pearlite, because the constituents ferrite and cementite have separated, though in an ultra-microscopic form.

With even more rapid chilling, the so-called martensite is obtained, characterised by an acicular structure. Although its nature is even now in dispute, my own view is that it is principally, if not wholly, austenite, the particular markings of which are caused by the stresses set up on quenching. If this view is correct then, constitutionally, austenite and martensite are the same thing, and exist above the line L S K, while troostite, sorbite, and pearlite are constitutionally identical, and exist below the line L S K. Illustrations of these structures will be found, with notes, on page 430.

Fig. 9, page 426, illustrates graphically the course of freezing of certain iron carbon alloys, and is modelled on one constructed by Professor Marion Howe.* Fig. 10 shows diagrammatically the proportion of ferrite, pearlite, and cementite in a series of steels containing ascending carbon. These figures and photographs enable the structural changes that occur in steels on heating and cooling to be followed.

SOME PRACTICAL USES OF THE EQUILIBRIUM DIAGRAM.

These may be said to begin at the moment when the liquidus line is approached, since the casting temperatures have an important influence on the properties of steels, but limits of space require that attention should be concentrated on aspects which in one form or another may all be included under one general heading, viz., the heat treatment of steel. This is now a highly skilled art, requiring as it does scientific knowledge, experience and judgment for its proper performance. It is in reality a special branch of engineering.

(*To be continued.*)

* "The Metallography of Steel and Cast Iron."

GERMAN WAR PROFITS.

THE Mathilden Hütte, Bad Harzburg, mining and iron works, is paying a dividend of 20 per cent. for last year. Shortage of fuel interferes with the working of the blast furnaces, but a speedy improvement is looked for. In the Friedrike mine, belonging to the company, further deposits of the usual good quality have been discovered, the life of the mine having thereby been established for a series of years.

The Brunswick Coal Mining Company, Helmstedt, is paying a dividend of 15 per cent. for last year; the prospects are satisfactory, provided the prices of coal and briquettes can be made to keep pace with the increase in cost of production.

The August Riedinger Balloon Company, Augsburg, is paying a dividend of 25 per cent. for last year and a 10 per cent. bonus of 100 marks per share in war loan. There are plenty of orders in hand and more are anticipated shortly.

The Continental Caoutchouc Company, Hannover, last year earned gross profits amounting to 11,128,957 marks, against 9,526,676 marks for the previous year, but the net profits receded from 9,172,139 marks for 1916 to 8,362,102 marks for last year, owing to increase under the heads of repairs, taxes and war-aid expenses; the dividend has been fixed at 30 per cent.; the holdings of stocks and bonds have increased from 20,800,000 marks to 27,600,000 marks.

The Sachsen Werk for Light and Power, Dresden, last year earned 6,030,856 marks, against 4,261,721 marks for the preceding year, and the shareholders receive a dividend of 30 per cent., against 20 per cent. for 1916. The turnover has increased very considerably and amounted during 1917 to 80,000,000 marks. The favourable position of the company is further illustrated by the holdings of stock and bonds having increased from 2,961,880 marks to 7,616,992 marks, and bank credit from 1,563,116 marks to 7,365,733 marks.

The Thale iron works is paying a dividend for last year of 26 per cent., as during the preceding year, and a bonus of 175 marks per share of 600 marks, against a bonus of 125 marks for the previous year. The turnover rose from 48,000,000 marks to 51,000,000 marks, and would have increased still further had it not been for the scarcity of coal during the last quarter of the year. The net profits amounted to 7,700,000 marks, against 8,400,000 marks for the previous year. The writings-off amounted to 2,600,000 marks, against 1,900,000 marks for the previous year, and the account for machinery and plant, which in the last balance-sheet figured for 1,700,000 marks, has now been written down to 1 mark. Holdings of stocks and bonds rose from 11,500,000 marks to 15,000,000 marks and bank credit from 5,800,000 marks to 14,500,000 marks. The company was very fully employed and the supply of coal has somewhat improved.

The large Scheidemandel concern, Berlin, has earned gross profits last year amounting to 11,540,000 marks, against 8,470,000 marks for the previous year, war reserves having been previously deducted. The share capital now amounts to 11,000,000 marks, with 6,510,000 marks visible reserve, and all the plant, &c., has been written down to 1 mark. Holdings of bonds, shares, &c., have increased from 7,560,000 marks to 13,540,000 marks, in which some shares have been put at a very low figure.

The Mannheim Steel Works is paying for last year a dividend of 20 per cent. and a bonus of 20 per cent.; a proposal to increase the dividend to 30 per cent. was negatived. The company has increased its production through the erection of new Bessemer works, now in operation.

The Hirsch Copper and Brass Works, which were amongst the first to create a sensation through their high war dividend, state in their report, as do a good many concerns, that the Hindenburg programme necessitated a vastly increased amount of employment and the erection of entirely new and separate works, equipped in the most up-to-date manner; so last year has been one of heavy outlays and preparatory work. The net profits amounted to 5,330,000 marks, against 4,960,000 marks for the previous year, and a dividend of 20 per cent. was again declared, this time on a capital of 15,000,000 marks, against 10,000,000 marks, the preceding year. Land stands booked at 1,600,000 marks, against 1 mark for 1916; buildings at 5,000,000 marks, against 2,000,000 marks the previous year, on account of the new works; and stocks, including materials for the latter, rose from 8,200,000 marks to 15,860,000 marks. Holdings of bonds and stocks amounted to 18,000,000 marks, including 13,000,000 marks German State loan. The Hirsch Company is interested in the Electoral Saxhse Lignite Gas and Power Company, which is expected to commence operation in the course of the forthcoming summer, in the Bavarian iron works, Fritz Neumeyer, which promises to yield satisfactory results during the current year and in the graphite industry of Northern, Bavaria, and has, with others started the Danube Crucible Company, where the graphite will be exploited.

The Saxonian Machine Factory, Chemnitz, which last year increased its capital by 3,000,000 marks, has to the full, as far as turnover tends to prove it, employed its increased capital under war conditions, the turnover last financial year being 30,550,000 marks, against respectively 17,340,000 marks and 15,580,000 marks for the two preceding years, the dividends being respectively 12.9 per cent. and 7 per cent., and no dividend for the four preceding years.

The Kronprinz Metal Industry Company, Ohligs, paid 25 per cent. for 1915, but only 15 per cent. for 1916, so as to consolidate the financial position, but the shareholders obtained a new share for each old one gratis, with 40 marks paid up, the capital represented by the old shares being 5,600,000 marks, the new gratis shares having the same aggregate value. It was also decided, that no higher dividend than 15 per cent. should be paid until the new gratis shares had been fully paid-up by the company. This is understood to have been about achieved, although the shareholders will only receive 15 per cent. this time.

The Gritzner Machine Works, Durlach, earned for 1917 net profits amounting to 1,375,397 marks, against 610,717 marks for 1916; the dividend has been fixed at 15 per cent., against 9 per cent. for the previous year, various funds having been well provided for.

The Cologne-Neu Essen Mining Union is paying a dividend of 40 per cent. for last year; the dividend for 1916 was likewise 40 per cent.

MERCHANT SHIPPING OUTPUT.—The tonnage of merchant vessels completed in United Kingdom yards and entered for service during the month of March, 1918, compared with preceding periods, was as under:—

Month.	Completions.	Year ended.	Completions.
1917.	Gross tons.	1917.	Gross tons.
March	118,699	March 31	602,225
April	69,711	April 30	749,314
May	69,773	May 31	773,116
June	109,847	June 30	833,863
July	83,073	July 31	865,147
August	102,060	August 31	928,470
September	63,150	September 30 ..	957,185
October	148,309	October 31	1,045,036
November	158,826	November 30	1,133,336
December	112,486	December 31	1,163,474
1918.		1918.	
January	58,568	January 31	1,173,953
February	100,038	February 28	1,194,540
March	161,674	March 31	1,237,515

The Controller-General of Merchant Shipbuilding makes the following comment: The figures for last month (March) of 161,674 tons constitute a record, and demonstrate that the workers have taken to heart the anxiety caused by the comparatively low output of January and February of 58,568 tons and 100,038 tons respectively. It will be seen that although there are fluctuations in the output of individual months, the annual output shows a steady upward tendency. The men in the shipyards are working loyally to maintain this increased output of tonnage.

ROYAL METEOROLOGICAL SOCIETY.

THE usual monthly meeting of this society was held on Wednesday, the 17th inst., at the Society's Rooms, 70, Victoria-street, Westminster, Sir Napier Shaw, F.R.S., president, in the chair. Mr. E. G. Bilham, B.Sc., F.R.Met.Soc., read a paper entitled "*The Variations of Underground Water Level near a Tidal River.*" The paper is chiefly devoted to a comparison of records from the Kew Observatory water-level recorder and the Richmond Lock tide-gauge for a period of two years, beginning May, 1914. The seasonal variations, determined from lunar-monthly means, were found to be very similar, as was to be anticipated on general grounds. A better method of determining the extent to which the variations of sub-soil water-level were directly controlled by the River Thames consisted in the analysis of the well records to find tidal oscillations analogous to those which were well-marked in the river. The well responds but slightly to the lunar semidiurnal tide, but the lunar-fortnightly oscillation is well reproduced with a lag of 5 days and a reduction of amplitude in the ratio of 1 to 14 (approximately). After allowing for the direct action of the river, the well is found to be very sensitive to local rainfall during winter months. The effects of rainfall upon river-level and underground water-level appear to be in many respects closely similar.

Mr. J. Fairgrieve, M.A., also read a paper entitled "*Suggestions as to the Conditions Precedent to the Occurrence of Summer Thunderstorms with Special Reference to that of June* 14, 1914." The paper deals particularly with the thunderstorm of June 14, 1914. The meteorological phenomena accompanying the rainfall are put on record. The cloud distribution, the barometric pressure, the wind movements and the temperature are specially dealt with. From an examination of the data it is evident that the clouds and the rainfields lie in parallel belts, and that the former appear some hours before the rain begins to fall. It is suggested that this belting of wind and rain may be due to rippling on a large scale, the rippling being brought about by the interaction of two currents of different temperatures. If the conditions are unstable and especially if relief also induces disturbance, thunderstorms will develop along lines of rippling and will drift with the wind. Thunderstorms have apparently three movements, a development along a belt, a sideways movement in the direction of the prevailing wind, *i.e.*, to leeward and a spread to windward. The first may be due to rippling; the second is a drift; the third may be explained if it is granted that a local ridge of high-pressure develops along the axis of the thunderstorm. The thunderstorm then breaks up into two belts of which the leeward soon dies out owing to a lack of a supply of rising air.

THE LATE MR. DANIEL MACALISTER.—We regret to have to announce the death, which occurred suddenly at his residence, Overton Cottage, Greenock, on the 12th inst., of Mr. Daniel Macalister, the engineer and superintendent of the Greenock Corporation Water Department. Mr. Macalister was born at Greenock; he served his apprenticeship with the Harbour Trust engineer, and acted as resident engineer during the construction of the James Watt Dock. After several years spent abroad, Mr. Macalister was appointed, in 1899, superintendent of the Greenock waterworks. He entered the Institution of Civil Engineers in February, 1882, and was made a full member of that Institution on September 21, 1891, to whose proceedings he contributed. He held the Institution's Miller prize, and was also a member of the Meteorological Society.

PERSONAL.—Lieutenant-Colonel J. R. Davidson, having now been transferred to the Territorial Reserves after serving with the British Expeditionary Force since the outbreak of the war, has resumed his duties as water engineer to the Liverpool Corporation since Monday, the 15th inst. Mr. Parry, who temporarily undertook Colonel Davidson's duties, will continue his consulting practice, and his office address will, for the present, be Alexandra Buildings, 55, Dale-street, Liverpool; his private address is Woodbury, Waterloo, near Liverpool. (Telephone, Waterloo 41.)—Mr. Alan E. L. Chorlton, C.B.E., has been appointed Assistant Controller of the Department of Aircraft Production, to deal with the production and supply of aero engines, excluding Rolls-Royce engines. Mr. Chorlton is a member of the Board of Invention and Research.

APPEAL TO SHIPYARD WORKERS.—Lord Pirrie, Controller-General of Merchant Shipbuilding, on Wednesday, the 17th inst., made the following appeal to the shipyards: "The German offensive has thrown an increased burden on the shipping resources of this country and its Allies. Enormously increased supplies of men, munition and war material have to be transported to France not only from this country but also from America. The shipping resources of the Allies were severely taxed before this additional burden was thrown on them. Our reliance on the United States for a noble answer to the Prime Minister's appeal has not been misplaced. It must be remembered, however, that every additional ship employed in sending this assistance means a corresponding reduction in the quantity of food that can be spent. Consequently an urgent appeal is made to the shipyard workers, employers and all connected with the construction of ships to redouble the splendid efforts already made. They can take an almost direct part in countering the enemy offensive. Though the actual fighting machine is the arbiter at the moment, shipping production is of equal importance and a matter of vital urgency."

THE OPTICAL SOCIETY.

AT the meeting of the Optical Society held at the Imperial College of Science, South Kensington, on April 11, the president, Professor F. J. Cheshire, C.B.E., in the chair, there was read a paper by Mr. J. W. French, B.Sc., on the subject of "*The Balsam Problem.*" For cementing optical parts together the author pointed out that Canada balsam is almost invariably employed. Although starting or starring of the balsam layer, actual separation of the parts, or deformation of the optical surfaces frequently occurs, there is no appreciably better substance known. Optical parts may be combined with an air space between the surfaces, by optical contact with or without sealed edges, by optical welding or by cementing. The disadvantages of the various methods were enumerated, the loss of light at transmission surfaces being particularly discussed.

The use of balsam and the present-day method of cementing were introduced more than 130 years ago by Abbé Rochon, and Grateloupe, assisted by the French optician Putois. Although far from perfect, the process has not yet been substantially improved since that time. The source, composition and qualities of Canada balsam were described, with special reference to optical work. A considerable number of balsamed specimens of ages varying up to ten years had been opened, and photo-micrographs of balsam layer were exhibited. In all cases there were fluid layers between the harder balsam and the glass surface, and the photographs demonstrated particularly the smallness of the adhesion to the glass.

Specimens artificially produced were also exhibited. In many cases the age of the specimen was shown to be deducible from the configuration. So-called granulation of balsam was stated to be due to the action of moisture on the balsam surface. No trace of crystallisation of good-quality balsam was found in any of the experiments, but a number of the photographed specimens showed definite right-angled fractures occasionally observed in torn gelatine films. A well-sustained discussion followed the reading of the paper, and a vote of thanks to the author concluded the proceedings.

QUEENSLAND MINERALS.—Queensland Geological Survey report in regard to industrial minerals, Queensland: "Very large areas exist in many parts of Queensland which have never been examined for deposits of minerals, not even those easily recognised and commonly used, such as ores of gold, silver, lead, copper and tin. Larger areas are available to the prospector for the discovery of minerals which are not so readily distinguished or are not so valuable, and practically the whole of the eastern half of the State has yet to be explored for the minerals we require in our industrial developments.

GOVERNMENT ORDER CONCERNING SMALL TOOLS.—In pursuance of the instructions of the Controller of Machine Tools, dated February 19, 1918, H.H.B./G.S., the undertaking to be signed by, or on behalf of dealers in engineers' and machinists' imported small tools, is now cancelled. The Ministry of Munitions has, however, imposed new regulations with regard to priority classification in respect of all small tools, whether imported or of British manufacture. The forms of priority classification certificates (sometimes known as "munitions certificates") can be obtained from all the principal post offices.

FRENCH LOCOMOTIVES AND ROLLING-STOCK.—In an article given in its issue for March, *La Technique Moderne* reviews the duty required of the steam locomotive, the effect of superheat and compounding and the working of the locomotive boiler, and states that the reorganising and development of railway transport in France are among the most urgent problems to be solved not only after the war, but even at the present time. It will be necessary shortly to renew the country's rolling-stock, which has been overworked during the last four years. A considerable increase in railway goods traffic is also to be faced. These conditions imply the construction of powerful traction units capable of hauling as heavy loads as possible at a speed closely approximating to the speed of passenger trains. Further, owing to the high cost of fuel, particular importance will attach to arrangements destined to reduce fuel consumption, by improving the utilisation of the steam in the cylinders, or by improving the steam-raising power of the boiler.

SULPHUR IN STEEL CASTINGS.—Before the war, says *The Iron Age*, New York, Government and railroad requirements imposed a maximum for sulphur of 0·05 per cent. in steel castings, and in some cases 0·04 per cent. was the limit. Under normal conditions, these were not difficult to meet in steel made by the acid and basic open-hearth, the crucible and electric processes. The converter process has always had its troubles in this respect. The war has changed conditions materially. Most Government castings are made by the acid open-hearth and converter processes. According to the experience of the largest producers of such castings in the United States, it is now practically impossible to turn out steel which will meet the old specifications. The raw materials, both the pig-iron and the scrap, are higher in sulphur. The result has been that users of such castings are now accepting without question metal running 0·06 per cent. of sulphur and higher, made in acid open-hearth, and still higher sulphur steel in converter castings. There seems to be no trouble with the metal when carefully and properly made. The endurance of such material in service, particularly in war, may bring out valuable information. Requirements in specifications are often based on theory and not on practice, resulting in hardship and loss to the steelmaker.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Local Markets.—Ever since the Easter holidays there has been experienced a shortage of coal, and firm conditions prevail—a state of affairs which had not been experienced for a very long time. The authorities can hardly be blamed for not having anticipated the present need. They sanctioned the full three days' holiday at Easter in the confident belief that the enormous quantity of coal then standing on the various sidings would be more than enough to meet their requirements; but recent events have proved how restricted is the stock accommodation in the coalfield. Little or no private business, however, is taking place. Smalls continue quite as scarce as large. The pits are doing well, but outputs are not on an average up to normal full time production, and it is feared that the calling-up of miners—and hundreds of them are volunteering without waiting to be combed out—will make it difficult if not impossible to increase production. Pitwood supplies are well maintained.

Newport.—The market continues firm for pretty well all descriptions of Monmouthshire coals, and supplies are, for the moment, hardly equal to the demand. There is, therefore, every indication that pits will be kept working regularly for some time, as there is hardly a likelihood of stocks accumulating.

The Allocation of Coal Orders.—Notwithstanding the fact that there is at present a shortage of coal, it has been decided to put into operation the scheme for the allocation of coal orders whereby outputs are restricted within fixed limits, and it came into operation on Monday. On that day a meeting of the South Wales Coalowners was held to consider the matter, and they decided to give their loyal co-operation and assistance to the District Coal and Coke Supplies Committee in giving effect to the scheme which, it was pointed out, would be a better alternative than the workmen's proposal for a five-days' working week.

LARGE HARBOUR WORKS AT HELSINGBORG.—Large extensions of the Helsingborg Harbour have been decided upon, the cost of which will amount to some 6,000,000 kronor, but the work has been left in abeyance owing to the extremely high prices ruling for all kinds of materials. It is, however, proposed to make a start now to counteract the large amount of unemployment, and to expend 3,500,000 kronor for this purpose.

ANTI-STATE MONOPOLY MOVEMENT.—At a highly representative meeting of leaders of Danish industries, between 700 and 800 gentlemen being present, a strong resolution was passed against State monopolies, the immediate occasion being a possible State tobacco monopoly, and a proposal introduced in the Legislature concerning further State monopolies. Mr. A. Foss, the eminent engineer, denounced all State monopolies, adding that the State could interfere with private combines, but in the case of State monopolies no control was at all possible. A resolution was passed unanimously asking for the establishing in the country of a sound and strong industry, one capable of giving employment to the country's available labour in the manufacture of products intended both for meeting the country's own needs and for exchange with other countries. This was a necessity, if Denmark's economical conditions were to be maintained and further developed. The situation could only be met by free and independent industrial concerns. The taking over by the State of branches of industry as State monopolies would impede the technical progress of industry, would lower the quality of the goods in proportion to the price, weaken the competitive power of industry, render all export trade difficult or impossible, would necessitate the adoption of high tariffs or an embargo on imports in order to maintain the monopoly, and as a result of all these effects would lead to increased taxation for the maintenance of the monopolised industry, which meant a taxation of other industries as well as of the consumers.

CATALOGUES OF TECHNICAL BOOKS.—On June 27, 1916, at the Royal Technical College, Glasgow, a meeting was held of representatives of 14 societies and institutions in the city. At this meeting a committee was formed to undertake the production of joint catalogues of technical books in the libraries of the societies and institutions represented. The Corporation Libraries Committee thereafter agreed to participate in the scheme, and Mr. S. A. Pitt, the city librarian, joined the committee. Under the auspices of this committee, catalogues are being prepared on different technical subjects, and it is hoped that eventually the complete field of technical literature (in book form) will be covered. The attainment of this object is a large undertaking, both as regards labour and expense, but already two catalogues—including the literature of "Aeronautics" and "Internal-Combustion Engines"—have been published, and a third—dealing with "Motor Vehicles"—is well advanced. The classification adopted is that of Melvil Dewey, with indexes which include both authors' names and subject matter; and, by means of reference letters, an indication is given of the library or libraries in which each book is to be found. These catalogues may be consulted at all the public libraries in the city, and may be purchased at 1*d.* each. The scheme is being financed by contributions from the Corporation of Glasgow Libraries Department and the participating societies and institutions. Professor Latta is chairman of the Joint Technical Catalogue Committee, and the honorary secretary is Mr. R. M. Neilson, of Atlantic Chambers, 45, Hope-street Glasgow. Mr. Pitt, the city librarian, is undertaking the editorial work.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scotch Steel Trade.—With every mill running at its fullest capacity the steel-making industry in the West of Scotland still maintains the exceptional activity which is now taken so very much as a matter of course. No new developments fall to be recorded although, in not a few cases, some considerable anxiety is felt regarding the text of the new Man-Power Bill and its effect upon certain branches of trade and industry. Under existing circumstances, the production of steel for national purposes is of too important a character for any vital change in the *personnel* of the steel-making establishments to be contemplated, unless such change would be in the way of increasing the number of skilled workers. Government control and supervision greatly aids the home consumer who is now supplied with material according to the urgency of his needs. The only export now being done is the small tonnage which goes to the Allies and our own overseas Dominions.

Malleable Iron Trade.—Business at the malleable iron works is as keenly active as ever, and rolling goes on unceasingly. The requirements of Government for war purposes of one kind and another, are so great that practically the entire output is reserved, leaving very little for ordinary export. Small sizes, involving a considerable amount of rolling, and sections are in great demand, and so also is bolt and cable iron. As in kindred industries the present critical struggle on the Western Front is making for a serious increase of work.

Scotch Pig-Iron Trade.—The demand for every grade of pig-iron is constantly on the increase. Notwithstanding the various drawbacks a marvellous output is being maintained, the whole of this being devoted to national purposes. No change in price has taken place.

Apprenticeships at Rosyth Dockyard.—In connection with the appointment of apprentices to Rosyth Dockyard, an interesting concession has just been made by the Lords Commissioners of the Admiralty, suggested to them by the Scotch Education Department. This is to the effect that when a headmaster can recommend a boy as being suitable, and can certify that this boy has successfully passed through a three-years' supplementary course, the Lords' Commissioners may nominate him to an apprenticeship provided that he pass an examination conducted by the Rosyth Dockyard schoolmaster. This examination is not so much scholastic, as to determine the selection of trade, and it is further guaranteed that no suitable candidate will be rejected on educational grounds.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

The Man-Power Bill.—Since the precise terms of the Man-Power Bill were published, there has been considerable speculation as to whether the provisions of the measure will be applied without modification to the Sheffield industries. There is a strong conviction that owing to the important character of the activities within the city, recruiting measures should only be applied after due consideration has been paid to the urgent nature of local work; but even while it is hoped that this indulgence will be forthcoming, there seems every probability that there will be certain phases of industrial life here which cannot escape the need for men for the forces. There are, for instance, numerous schemes of work extension already well in hand, which, it is feared, will be deprived of labour. At the moment of writing, developments in the new call for men are somewhat anxiously awaited.

Extension of Works.—Even though it were certain that the latest recruitment proposals would fall locally only on the labour engaged in the extension and remodelling of works, the effect in that direction would be very widespread. For a considerable period now firms have been launching expansion schemes, and the number of places where these schemes are already well in hand is very large.

Iron and Steel.—Since last week the conditions in the steel trade have undergone no appreciable change. In the heavy department makers are being fully occupied. The chief product in the industry at the moment, however, is the acid steel, the local supplies of basic steel being furnished from outside. There is an insatiable demand for aircraft steel; and it is probable that a further acceleration in shell output will appear in the immediate future. The boom in shipbuilding has created a shortage of steel plates, In the lighter branches of Sheffield trade, makers are inundated with orders. The wholesale trade maintains an active character, but though there are comparatively few obstacles placed in the way of firms for obtaining materials there is a scarcity of labour. Under the pressure caused by the enlistment of grinders, in many places, machinery, obtained only with great difficulty, is being installed to do the work formerly done by hand, an expedient which, of necessity, must be in practice some time before a perfect degree of satisfaction can be attained. Compared with business at this time in 1917, the Government demand for knives is not so brisk. Supplies of pig-iron continue to be scarcely equal to the requirements.

South Yorkshire Coal Trade.—The demands for coal are considerably in excess of the output. Matters were considerably interfered with through the Easter stoppage at the pits, and with many orders still unsatisfied, the prospect of men to be yet taken from the collieries for military service, does not naturally improve the situation. The demand for all manufacturing fuels is specially great. While export tonnage, mainly for Government requirements, shows very little change, home consumption remains at a high pitch. Large coal and cobbles are obtainable in good quantities, but the same cannot be said of steam nuts. Gas fuels are very keenly sought. Quotations:—Best branch handpicked, 23*s.* to 24*s.*; Barnsley best Silkstone, 23*s.* to 23*s.* 6*d.*; Derbyshire best brights, 21*s.* to 22*s.*; Derbyshire house coal, 18*s.* 6*d.* to 19*s.* 6*d.*; best large nuts, 18*s.* 6*d.* to 19*s.* 6*d.*; small nuts, 17*s.* 6*d.* to 18*s.* 6*d.*; Yorkshire hards, 18*s.* 6*d.* to 19*s.* 6*d.*; Derbyshire hards, 17*s.* 9*d.* to 18*s.* 9*d.*; best slacks, 14*s.* to 14*s.* 6*d.*; seconds, 13*s.* to 13*s.* 6*d.*; smalls, 9*s.* to 10*s.*, per ton at the pit.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—There is a moderate business passing in Cleveland pig-iron on home account, but export transactions are still on only a very limited scale. A few supplementary allocations have been issued, and the truck supply, though still far from what could be wished, shows improvement, with the result that much needed deliveries are heavier to some home customers. For home consumption, No. 3 Cleveland pig-iron, No. 4 foundry and No. 4 forge all stand at 95*s.*, and No. 1 is 99*s.*; and for shipment to France and Italy, No. 3 and the lower qualities are 114*s.*, and No. 1 119*s.*

Hematite Iron.—The extensive and still growing use of basic iron for steel-making serves the double purpose of reducing import of foreign ore, and relieving the pressure for hematite iron. All essential home needs of hematite are now regularly met, and a surplus supply is available for export. Conditions are thus nothing like so stringent as they have been, and further relief is confidently looked for. Nos. 1, 2 and 3 East Coast hematite are 122*s.* 6*d.* for home use and 147*s.* 6*d.* for shipment to France and Italy.

Manufactured Iron and Steel.—Producers of manufactured iron and steel are very fully employed, and are turning out huge quantities of material for the Government and for the shipyards. Distribution of output is still strictly controlled, but the system is working smoothly, and, on the whole, satisfactorily, and shipbuilders, at least, are assured of ample supplies of material. Prices are very stiff, but unaltered.

Another Large Works Amalgamation.—Yet another large deal has been made in connection with the Middlesbrough iron trade, the East Coast Steel Corporation having acquired the whole of the properties of Messrs. Cochrane and Co., Limited, who, in addition to their Ormesby Ironworks, consisting of four blast furnaces, their huge pipe foundry, and well equipped wharf at Middlesbrough, own one of the best collieries in County Durham and are the possessors of ironstone mines at Stanghow, in Cleveland. The East Coast Steel Corporation is a combine of interests of the Furness group, of which Lord Furness is chairman and Mr. Benjamin Talbot managing director, and is at presented committed to a scheme for the construction of huge steel plant on the north side of the Tees, opposite Middlesbrough. Amongst the interests of the corporation are the extensive Cargo Fleet Ironworks at Middlesbrough, which are in close proximity to the Ormesby Ironworks. The firm of Messrs. Cochrane was established at Middlesbrough in 1854 by the late Mr. Alexander Brodie Cochrane, who went to Teesside from South Staffordshire. Seven years later the pipe foundry was started, and subsequently the firm became colliery owners, and ironstone mine owners. The works at Middlesbrough have a river frontage to the Tees of 1,100 ft., and on the wharf are erected a number of large electric cranes capable of dealing with ships up to 5,000 tons. Messrs. Cochrane employ over 3,000 hands.

BRITISH ENGINE, BOILER AND ELECTRICAL INSURANCE COMPANY, LIMITED.—At the annual meeting of this company, held in Manchester last week, Mr. R. Charles Longridge, the chairman, said he was pleased to report that the results of the year had been satisfactory having regard to all the circumstances. There had been a marked development in the business of the company, the inspection fees and premiums having increased to 141,875*l.*, as against 125,851*l.* in the previous year. The explanation of this increase was that a very large amount of additional electrical plant had been insured with the company in order that the owners might have the benefit of the company's inspection service. Many firms had candidly told the company that whilst in the past they had been prepared to run their own risks, they now felt that with plant in charge of insufficiently experienced workpeople it was desirable to take the precaution of having it under independent inspection with a view to preventing stoppages. Other clients had been much impressed by the increased cost of effecting repairs, and were also influenced by the fact that it was an advantage, in the event of a breakdown, to have the assistance of the company's engineers both in deciding what repairs should be carried out and in attending at the repairing shops to see that the work was satisfactorily completed. As an illustration of the possible economics to be achieved by the supervision of the repairs by the company, the chairman mentioned the case of a breakdown where three quotations had been obtained, the charges being in the ratio of 100, 240 and 480 respectively. In the matter also of preventing breakdowns through regular inspections, the company constantly received letters expressing appreciation of the services rendered. The company, added Mr. Longridge, felt that they were performing a work of great national importance by obviating the necessity for repairs and thus relieving the strain upon workshops.

NOTICES OF MEETINGS.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Friday, April 19, at 6 p.m., in the Lecture Theatre of the Literary and Philosophical Society, Westgate-road, Newcastle-on-Tyne, the following lecture will be given: "Some Aspects of the Naval War," by Lieutenant E. H. Gordon, R.N.R. Tuesday, April 23, at 6 p.m., a paper on "The Future of Aerial Transport," by Mr. G. Holt Thomas. The lecture will be illustrated by cinematograph films.

THE ROYAL SOCIETY OF ARTS.—Monday, April 22, at 4.30 p.m.: Cantor Lecture, "Military Explosives of To-day," by Mr. James Young, O.B.E., A.R.C.S., F.C.S., Chief Instructor in Science, Royal Military Academy, Woolwich. Wednesday, April 24, at 4.30 p.m.: Ordinary meeting, "Mental Effects of the War and their Lessons in Social and Medical Reconstruction," by Major Sir Robert Armstrong-Jones, M.D., F.R.C.S., R.A.M.C. The Right Hon. Lord Sydenham, G.C.M.G., G.C.I.E., G.B.E., F.R.S., will preside.

THE INSTITUTION OF CIVIL ENGINEERS.—Tuesday, April 23:—5.20 p.m., ordinary meeting, for the purpose of a ballot of candidates for election; 5.30 p.m., annual general meeting of Corporate Members only, to receive the Report of the Council, and to elect the Council and Auditors for the ensuing year. On the conclusion of the annual general meeting, special general meeting, for the purpose of dealing with an amendment of the by-laws.

THE ROYAL SANITARY INSTITUTE.—Wednesday, April 24, at 5 p.m., at 90, Buckingham Palace-road, a discussion will take place on "Housing: Planning and Materials, Permanent and Semi-permanent," to be opened by Mr. Frank Baines, M.V.O., F.R.I.B.A. (Principal Architect, H.M. Office of Works). "Housing Fitments and Conveniences," by Mrs. Sanderson Furness (Honorary Secretary Housing Sub-Committee, Women's Labour League).

THE CONCRETE INSTITUTE.—Thursday, April 25, 1918, at 5.30 p.m., at Denison House (close to Victoria Station), when a Paper will be read by Mr. J. H. Deane, M.Inst.C.E., &c., on "The Charterhouse Street Cold Stores of the Port of London Authority."

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, April 25, at 6 p.m., at the Institution of Civil Engineers, Great George Street, Westminster, S.W. A paper on "Large Batteries for Power Purposes" will be read by Mr. E. C. McKinnon, Associate Member.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, April 26, at 5.30 p.m., a discourse will be delivered by Sir A. Daniel Hall, K.C.B., F.R.S. The subject will be "Food Production and English Land." Afternoon Lectures, at 3 p.m.:—Tuesday, April 23: Professor Arthur Keith, M.D., F.R.S., Fullerian Professor of Physiology, Royal Institution, on "Barrow Explorers" (Lecture I.) Thursday, April 25: Sir Isambard Owen, M.D., LL.D., on "Rheims Cathedral" (Lecture I), Saturday, April 27: Professor H. F. Newall, D.Sc., F.R.S., on "Modern Investigation of the Sun's Surface" (Lecture I).

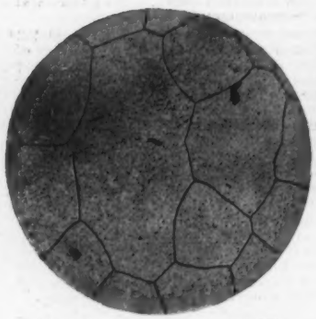
COTTON—ADDENDUM.—With reference to our note on the above subject on page 404 of our last issue, Dr. Balls wishes us to emphasise the fact that the neglect of drainage from which the cotton crop in Egypt has suffered is *past* neglect and that most important reforms in this connection are now in progress.

THE SHIPBUILDING, ENGINEERING AND STEEL COMMERCIAL STAFFS' ASSOCIATION.—The second lecture in connection with the above association, entitled "Insurance," was given by Mr. A. E. Lister on Monday evening, the 15th inst., in the Church Institute, Hood-street, Newcastle-on-Tyne. Mr. Mathieson, the president of the association, occupied the chair, and in introducing Mr. Lister to the members, intimated that he was very pleased to say that the lecture was the second one the association had arranged and that the association was very fortunate in securing the valuable services of Mr. Lister to deal with this important part of the business. He also stated that since the Commercial Staffs. Association was launched it had about 500 members, and the 500 members represented 30 of the prominent shipbuilding, engineering and steel industries on the East Coast and also representation from Hull; therefore he hoped through time to make this a national movement.

BUILDING MATERIALS INQUIRY.—The committee set up by the Minister of Reconstruction to ascertain what steps may be taken to ensure adequate supplies of all kinds of building materials during the transition period immediately following the cessation of hostilities is instituting a general inquiry as to the probable consumption of materials during that period. In co-operation with the R.I.B.A., the National Federation of Building Trade Employers and other federations and associations interested, the committee have drawn up forms of return with regard to: (1) New building works to be begun after the stoppage of hostilities; (2) works, the erection of which was begun but was stopped by the direction of the Ministry of Munitions; (3) building works proposed to be undertaken for public local authorities. These forms of return are being sent to architects and builders and to local authorities throughout the country, and the committee hope that in the interests both of the nation and of the individual they will be filled in and returned, thus assisting materially the work of the committee. Any inquiries on the subject should be addressed to The Secretary, Building Materials Supply Committee, 6A, Dean's-yard, Westminster, S.W.

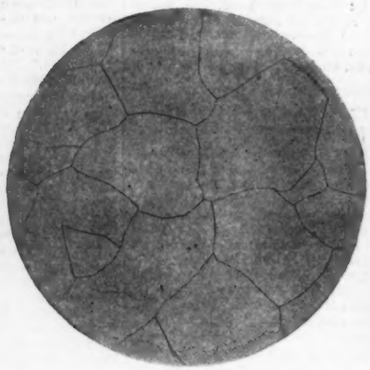
THE IRON CARBON EQUILIBRIUM DIAGRAM.

(*For Description, see Page* 426.)



× 100

No. 1.—γ iron (austenite).



× 80

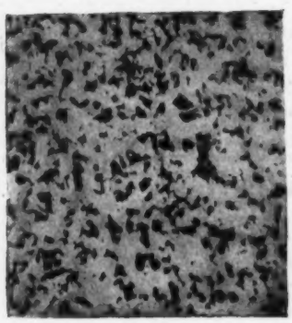
No. 2.—Chemically pure α iron (ferrite).

× 100

No. 3.—Commercially pure α iron (armco).

× 100

No. 4.—Wrought iron (α).
The black patches are threads of slag elongated in rolling.



× 100

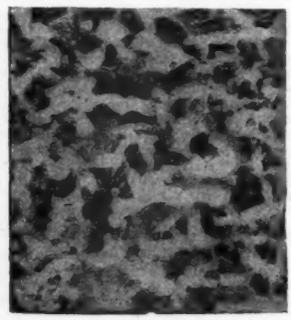
No. 5.—Steel containing 0·29 per cent. of carbon (as rolled).
White patches ... α iron.
Dark patches ... pearlite.

× 100

No. 6.—The same steel quenched in the area G O S L.
White patches ... unabsorbed iron.
Dark patches ... altered austenite, i.e. martensite.

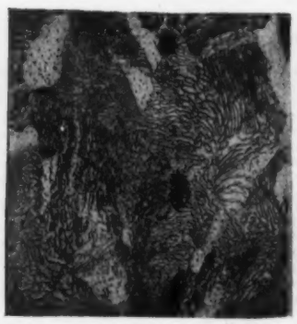
× 100

No. 7.—The same steel quenched in the austenite area consisting entirely of altered austenite (martensite).



× 100

No. 8.—Steel containing 0·49 per cent. of carbon annealed
White areas ... α iron.
Dark areas ... pearlite.

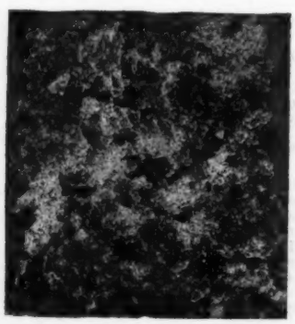


× 350

No. 9.—A pearlite area (No. 8) magnified so as to show the lamellar structure of the pearlite.

× 100

No. 10.—Same steel as No. 9 quenched from 900° C. It consists principally of martensite with which are mixed small black patches of troostite.



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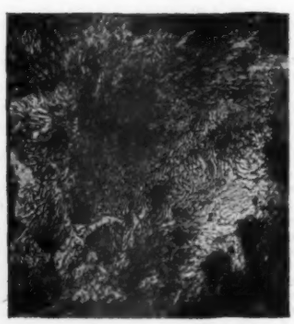
No. 11.—Steel containing 0·90 per cent. of carbon, consisting wholly of pearlite and eutectoid composition. Point S on the equilibrium diagram.



× 350

No. 12.—Same steel (as No. 11) more highly magnified. It shows
(1) Banded or lamellar pearlite.
(2) Unresolved pearlite (sorbite).

AMERICAN GOODS TRAFFIC ORGANISATION.—The "shipping day" or "sailing date" plan for accepting and forwarding less-than-carload freight on the Pennsylvania Railroad has now been extended to cover the service on all of the 25 divisions east of Pittsburgh and Erie. Schedules providing "shipping days" for each division have been worked out, and the new method placed in actual operation on all portions of the eastern lines. While the management of the Pennsylvania Railroad believes that further study of less-than-carload traffic, and longer experience with the "shipping day" plan will probably point the way to additional economies, beneficial results have already been achieved, with the general co-operation of the shipping public in making the plan successful. Reports from all divisions, which have just been compiled, show that a total of 654 cars are being saved daily in the transportation of less-than-carload freight on the lines east of Pittsburgh, through the operation of the "shipping day" plan. In addition, 25 distributing local freight trains per day have been discontinued altogether, by substituting tri-weekly or semi-weekly "pickup" service for daily service on divisions and branches where traffic is light. The crews of these trains have been transferred to other and more essential duties elsewhere in the freight service, and the locomotives and cars are being similarly utilised. The purpose of the plan is, as far as possible, to concentrate less-than-carload freight automatically into carloads, each for a single destination, at the point of origin. With this object in view, shipping days have been established for each station, to various specified destinations. Less-than-carload freight is accepted only on the dates named and the cars leave at definite hours, as per published schedules. Five-and-a-half months' experience with the "shipping day" plan has shown that it not only economises in the use of car space, but gives shippers more regular service and reduces the length of time shipments are in transit. Moreover, by largely eliminating rehandling at freight transfer stations it has lessened loss and damage and the amount of freight going astray. It has also been effective in reducing congestion of teams and trucks at freight stations, and has economised in the amount of labour required, both by shippers and by the railroad, in handling less-than-carload freight.

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Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than 1 p.m. on Tuesday in each week.

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Foreign and Colonial subscribers receiving incomplete copies through newsagents are requested to communicate the fact to the Publisher, together with the agent's name and address.

All accounts are payable to **"ENGINEERING," LIMITED.** Cheques should be crossed "Union of London and Smith's Bank, Limited, Charing Cross Branch." Post-Office Orders should be made payable at Bedford-street, Strand, W.C. 2.

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We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.
TELEPHONE NUMBERS—3668 and 8596 GERRARD.

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With One One-Page Plate of TRIPLE-EXPANSION PUMPING ENGINES FOR THE LONDON COUNTY COUNCIL, and Three One-Page Plates of the WINCOTT FURNACES.

NOTICE.

Owing to the recent Government restrictions, and to the enormous increase in the price of paper occasioned thereby, the Proprietors of "ENGINEERING" are compelled to advance the price of this Journal further from 8d. to 9d. per copy. This increase dates from and includes the issue of Friday, March 1, 1918. The change will not apply to unexpired subscriptions.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper, and of the consequent shortage of supplies, readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk. Owing to the scarcity of paper it will be impossible in future fully to provide for a chance demand for this Journal.

NOTICES OF MEETINGS.

Notices of Meetings to take place during the present and next week will be found on page 429.

DEATH.

GRIFFITHS.—On the 13th inst., at Carisbrooke House, Stonehouse, Glos., Griffith Griffiths, in his 77th year.

ENGINEERING.

FRIDAY, APRIL 19, 1918.

SKILL AND INTEREST.

MANY are the schemes put forward for industrial reconstruction, indeed it seems as if every public individual, fitted for the task or not, has views on this question of the hour. A great deal of such published matter shows a want of practical knowledge on the part of these exponents of a new heaven and a new earth. Apart, however, from inside knowledge, when a man of fine and proved imagination brings his faculties to bear upon industrial matters his views are worth consideration and patient attention.

Professor L. P. Jacks, Principal of Manchester College, Oxford, and editor of the *Hibbert Journal*, the author of some charming books distinguished by their penetrating imaginative quality, asks in an evening paper (*The Star*) as to who in the future will do the uninteresting work like shovelling coals, posting dull things into dull books, and so forth. His views are distinctly Ruskinian, he wants the quality of work improved that the workman may be raised. A perusal of the article by a skilled mechanic is educative, since he finds that his lot in life is really cast in pleasant places. Take, for example, the formula as to desirable work italicised by Mr. Jacks. *That every man shall enjoy his day's work, and a good article come out at the end of it.* He further defines "Work that can be enjoyed" as work that we know to be worth doing—either for its thoroughness, or its beauty, or for the benefit it confers on mankind, or for all these reasons together.

Wherein is the skilled work of the engineer craftsman different? There is the usual gird at machinery so often in the mouth of the social reformer, but the author admits that machinery "provides a great deal of this class of work," *e.g.*, desirable work. Curiously enough, a locomotive driver is the illustration chosen. A trained engineer would perhaps have chosen differently; indeed, it is certain that he would.

There can be no quarrel with the statement which follows: "Imagine all the multitudes of earnest men, who are now pondering the question of education, with their eyes suddenly opened to the primal truth that the only educated man is the man who understands his job, and has a job that is worth understanding; and that the only education that is worth the name is education of Labour by Labour for Labour—Labour being in Professor Lethaby's fine phrase, 'the very subject-matter of life' and the password to all that makes life worth living."

Nor with the passage, "The right function of machinery is to do as much as possible of the dirty, monotonous, uneducative work of society, leaving as much as possible of the skilled, enjoyable, educative work to be done by *men*." And again: "The kind of work a man does will remain to the end of the chapter the factor that determines, more than everything else taken together, whether the man shall be happy or miserable, satisfied or restless, moral or immoral. Bad work makes bad men, good work makes good men: as is the work so in the long run is the man."

The present writer has at various times and in diverse places formulated the same arguments in much the same words. It is, however, interesting to find an Oxford Professor endorsing the claims of the skilled mechanic that his work is of the highest calibre. This increasing interest in manual work on the part of highly intellectual men, aside from its practice, leaves room for future hope. It is the dream of the engineer—realised in part—to set man free from drudgery, free from bondage, so to organise and transform the worst features of industrial toil, that the future world shall be a better place to live in, free from degrading and soul-destroying menial tasks.

Where Professor Jacks goes astray is that he ascribes the worst features of industry to the employment of mechanism—in this no engineer will agree. It is merely bad social organisation, not mechanism which has led to conditions deplored by all thoughtful critics. The instances he quotes as to unenjoyable work, shovelling coals, attending a lift, signing receipts, show him apart from real knowledge; all such work will ultimately be done by mechanism not by men; when he speaks of millions shovelling coal in Europe, it is exaggeration, in view of the enormous tonnage which is to-day handled by mechanical means.

Professor Jacks desires to undo the tyranny of the machine which has now existed for 150 years, and states that civilisation will take 150 years, all hands willing to the task, to undo the mischief. In another 150 years, in spite of such developments, there will still be drudgery, but it will not be muscular drudgery, for this will have vanished entirely. It may safely be taken for granted that all muscular drudging toil dealing with large bulks of material, can be eliminated by mechanical means. There will of necessity remain some menial work mostly of a household character, but the irreducible minimum of this is not even within sight, and the extension of mechanical appliances in a domestic sense is over due.

The hope of the future and the real benefit and comfort of all its citizens is bound up with the universal extension of mechanism to toil. There are, for instance, more ways than one of viewing work. Most work tends to grow monotonous. There is more than one sort of pay; indeed, reward may be classified as actual payment, amount of leisure and the sheer interest of the work. The two first are benefited by mechanism, and as to the last, in too many instances the machine makes a better job than the unaided man, and control of the machine has its own pleasure. After all, when an Oxford professor steps down into the realm of practical affairs, his views are interesting, but whatever the acuteness of his mind he lacks the knowledge necessary to appreciate the things outside his understanding, and assuredly the editor of the *Hibbert Journal* is the last to be able to assess the value and the future of mechanical art.

There is a cumulative destiny before the engineer, unmatched in any era of the world's history; to return to pre-mechanical days in the sense of hand craft is unthinkable; it would restore conditions more menial and far less comfortable, than those of the present time. The ideal of the engineer is communal service, the worst features of the industrial world are not his creation at all, indeed it is his efforts and only his efforts which can relieve them. Think of the mediæval times when alternate pestilence walked hand-in-hand with periodical famine, when the lot of the worker, whatever the romance of the period, was appalling in the extreme. Over the title page of every work on economics should be a tribute to the engineer, for the modern world is wholly his creation.

Sometimes one is led to wonder whether the social reformer, the imaginative idealist and the other critics of civilisation ever let their speculations wander to the fullest evolution of mechanism—subordination of self to the common end for subsistence for a short period of every day, bringing

leisure and rational life in full measure to all. We have large employers who foreshadow a six-hour day, and the intensive culture of mechanical art hand-in-hand with scientific discovery will progressively shorten the period. The increase in total wealth by multiplying effort many times over will enable the greater portion of a worker's life to be his own. Two things are necessary to the future—increased, not diminished, mechanism, and that every individual shall work—it shall be a disgrace to be idle, folly to do by hand what is more efficiently done by the machine.

VIBRATION: MECHANICAL, MUSICAL AND ELECTRICAL.

THE importance of the discourse on "Vibrations—Mechanical, Musical, Electrical," which Professor Edwin H. Barton, D.Sc., F.R.S., delivered at the Royal Institution last month, must not be judged by the small amount of space we can give to it under the pressure of other matter. Analogies such as he dwelt upon are the most fruitful aid of the instructor, and it is only the master of his subject who can risk their development without fear of being misled by them. Our difficulty is that the proper representation of the analogies which Professor Barton has worked out of late, in conjunction with Miss H. M. Browning and some of his students at Nottingham College, would require many illustrations.

Typical vibrations, Professor Barton pointed out, might be classified as "free, forced, coupled, compound" vibrations, and also as "mechanical, electrical, musical motions systems," and thus be grouped in columns and rows; that was only one of many possible classifications and might be extended. The simple pendulum described free vibrations which friction slowly extinguished. When the point of suspension was itself slightly moved to and fro by some periodic forces, the vibrations were forced and depended upon the "tuning," *i.e.*, the degree of agreement between the natural period of the pendulum and that of the forces, as to amplitude and as to phase. When the forces alternated at appreciably slower rate than the natural vibrations, the two pendulums would almost be in phase; when the forces changed more rapidly, in opposite phase; the closer the tuning, the better was the response. To demonstrate this, Professor Barton suspended several pendulums from a tightly stretched cord; the first pendulum had a heavy bob; when it was made to oscillate, it acted as "driver" on a pair of light pendulums (celluloid balls), one being longer, the other shorter than the driver, and the two settled to oscillations in opposite phases. The energy of the light "driven" pendulums was taken from the heavy driver, which suffered little by the loss. When one of two pendulums of equal masses was struck, the other also started oscillations which attained the same amplitude; but the driven bob sent energy back to the driver, and this surging to and fro of energy between the two was characteristic of the coupled vibrations, whilst with the disparity of the masses in the former case of forced vibrations there was only action of the driver on the driven bob, but hardly any reaction. In principle the two cases did not differ, coupled vibrations being reduced to forced vibrations with small coupling and comparatively large driving mass. The vibrations of both the two coupled bobs seemed quite simple, but they waxed and waned in amplitude exhibiting "beats"; beats were heard when two tones of slightly different pitch were sounded together, the number of beats per second being the difference of the frequencies of the two notes. Similarly the waxing and waning vibration of either pendulum might be regarded as the superposition of two simple vibrations of slightly differing periods.

In the next demonstration one bob was suspended from the ceiling and a second bob suspended from the first; when one of them was struck, the other started moving, but not as just explained; the second pendulum moved, paused a little, restarted again, and so on. This difference was due to different period ratios of the superposed vibrations, itself due to different degrees of coupling; the coupling, loose in the former case, had become tight, and the nearly equal periods had passed into periods at a ratio exceeding 2:1, which involved the pause or twitch. To bridge the gap between the two types of apparently unlike motion, Professor Barton devised his cord and lath pendulum. A wooden lath weighted below at P is the first pendulum VP; on the lath slides a stud C to which a cross arm DD_1 is attached, from the ends of which two pendulums D Q and $D_1 Q_1$ are suspended by looped strings of equal lengths; Q and Q_1, are cross-connected by a rod. For a short distance DD_1 the value of the coupling was approximately—the relation was not so simple in reality—represented by the ratio OC:CP; when the ratio was unity, the coupling was, for equal pendulum masses and equal lengths, $1:\sqrt{3} = 58$ per cent. The bobs were formed by funnels charged with sand, so that the escaping sand traced a curve on a black board held underneath the bob.

We should already have mentioned the electrical analogies. The current oscillations in a Leiden jar circuit of small resistance, Professor Barton explained, represented free vibrations; the inductance measured the electro-magnetic inertia. When a circuit of capacity and small inductance (a Fleming cymometer) was placed near—not too near—a circuit of similar frequency, but much greater inductance, the former would respond to the latter by forced vibrations, without appreciably diminishing the oscillations of the latter. When the two inductances and the two periods were comparable, the driven system would react on the driving by coupled vibrations. With very close coupling the primary oscillation was rapidly damped, so that the coupling was broken (after the energy had been transferred to the secondary), and the secondary was left free to oscillate at its own natural period; this was the case of the quenched spark of Max Wien and of the Telefunken radiotelegraphy system with a very short spark gap between large electrodes. The acoustical analogues were the free vibrations of a single tuning fork, the forced vibrations of a tuning fork under electromagnetic excitation (a hummer); the coupled vibrations of two equal tuning forks in proximity (resonance); and the compound vibrations of musical instruments.

The electrical vibrations, the lecturer continued, seemed to be simpler than any mechanical analogy yet devised. But Professor Barton's further apparatus explained many difficulties. In one of these apparatus, the double-cord pendulums, two strings, the "bridles," were stretched, more or less tightly, parallel to one another, in parallel planes; they were held together in the middle by a horizontal rod or tube, from the ends of which sand-funnels were suspended by adjustable loop cords; one of the bobs was made to oscillate at right angles to the parallel planes; underneath the pendulums was a horizontal black board which was slowly pulled along so as to receive the escaping sand. The bridles would sag (droop) under the weight of the pendulums and the coupling could be varied from 1 to 60 deg. per cent. by varying the droop; the greater the droop, the higher the coupling. As the coupling was tightened the appearance of the phenomena changed from slow beats to compound harmonic motion. For equal pendulum masses and lengths, the vibrations of the primary (the one excited) and the secondary pendulum would in turn pass through the same maxima and minima, *i.e.*, there would be the same waxing and waning of the amplitudes of a cycle. But when the primary was very heavy (20:1), the vibrations were forced, the primary vibrations being all of the same amplitude, not showing any cyclic change, while the secondary amplitudes increased and decreased. When the heavy pendulums was relatively short, a new feature appeared as the coupling was increased; the ratio of the periods first diminished to a minimum and then rose again, which meant that the number of vibrations in a beat cycle increased first and thus decreased again. These and other cases, illustrated by the lecturer, had been theoretically predicted and then experimentally been confirmed.

Professor Barton then passed to musical vibrations, a field in which he has successfully broken novel ground. We must confine ourselves to a few remarks. Musical instruments, he pointed out, usually gave compound vibrations of the pedal (lowest) note and its harmonies. That the F between the lowest C and its octave, could be obtained on brass instruments, was puzzling to theoreticians; but he had explained its existence, which depended upon the diffused resonance of the pedal and the intentional mistuning with respect to the higher notes; as the pedal was rarely sounded, the tuning was adapted so as to secure clear high notes. With respect to string instruments the physicist told the musician all about the vibration of a string, which could be bought for a few shillings, but gave little advice as to the influences of the manner of playing, of the bridge, the belly, the air holes, the mutual reactions of the light and heavy strings and other features of a violin, which was worth thousands of pounds. By fixing small mirrors and diaphragms to these parts, Professor Barton has studied these vibrations, and he exhibited many interesting photographs showing the modulations which the monochord vibrations underwent in the played instrument. His concluding remarks were certainly justified: "music lovers and scientists are much indebted to instrument makers, who have received little help from science in return. It is time that science pays off its debt to the musical craftsmen and makes the British piano second to none in the world."

THE REVIVAL OF GERMAN PEACE INDUSTRIES.

THE first months of the year have brought the usual number of reports and balance-sheets from a variety of German industrial concerns, and these have shown increasing dividends, unprecedented reserves and writings-off, and ever-swelling bank credits and holdings of stocks and bonds. It has even been stated, that if the war goes on much longer all the German plants will stand booked at 1 mark each. This is doubtless an exaggeration, but in several concerns, where the writings-off have been carried to extremes, the whole plant now stands in the books at that value. Whilst this happy condition of affairs particularly applies to those industries engaged on war contracts, it is by no means confined to it, and last year has been described as the year of renaissance of the German peace industries.

During the first year of the war all industrial branches which did not, directly or indirectly, work for military requirements, were forced into the background and they were, on an increasing scale, deprived of labour, raw materials and the means of transport. It was believed that if they were to keep going, they, too, would have to undertake the manufacture of munitions. The Hindenburg programme, towards the end of 1916, with its immense extension of the production of ammunition, offered opportunities to firms which had been entirely confined to peace work for getting a share of war profits. As a result, linen factories, makers of musical instruments and even stores, without giving up their legitimate business, also embarked upon the manufacture of shells, &c. This change no doubt accounts for the recently improved financial position of the peace industries, but this improvement emanates from conditions produced by the war. Besides this more apparent and transitory improvement there has been, during the year 1917, also another and more real improvement noticeable. A number of industries, dealing with such subjects as glass, pottery, porcelain, furniture, wine production and *articles de luxe* have done exceedingly well during 1917 after some trying years. This has been particularly manifest at the last Leipzic Messe, where the demand far exceeded the offers and the capacity of the exhibiting firms. The position may be summed up in two words: shortage of goods and superabundance of money.

The favourable effect of higher prices has also shown itself in relation to industries which stand between those specifically connected with war and with peace, such as breweries, jute factories, textile works and more especially the cement industry, which all were able materially to increase their dividends for 1917. Even undertakings which, according to official restrictions, were lying idle,

managed satisfactorily through the subsidy they received, provided they made the best of other chances. A peculiar feature in many balance-sheets for 1917, especially for concerns which originally produced the products of peace, is the distributing of a bonus, in addition to the regular dividend, which means that the bonus represents an extra or exceptional profit arising from the abnormal circumstances and which is likely to be of only a transitory nature. When, however, the bonus becomes a regular and recurring thing, it simply means, that the exceptional profits are in a way becoming the rule.

The bonus has also, in not a few cases, to compensate the shareholder for the discontinuance of opportunities to obtain shares in new issues at par, or at some extremely low rate, when the old shares are perhaps quoted at several hundred per cent. premium. This system, which in at least one notable instance has been seriously abused, has been frustrated by a late decree, which places the issue of new shares under the control of the Prussian Minister of Commerce, as far as Prussia is concerned, and this official seems to refuse permission to issue free shares or shares at par.

A few results of last year's working will bear out what has been said about the revival of the more or less definite peace industries. Several cement factories have already declared 10 per cent. dividend for last year, against very small or no dividend for 1916. The Wessel Porcelaine and Stoneware Factory in Bonn, shows a net profit of 548,459 marks for 1917, against 7,973 marks for 1916, and a loss carried forward of 484,537 marks. The Gerner Jute Spinning Mills, Trieben, which has taken up a kind of substitute manufacture, had net earnings for 1917 of 1,028,752 marks, against 532,746 marks for the previous year; dividends of 36 per cent. and 30 per cent. on shares A and B, against respectively 22 per cent. and 16 per cent. for the preceding year were declared. The Hanseate Jute Spinning and Weaving Mills, Delmenhorst, last year earned 768,894 marks, against 411,100 marks for the previous year, dividends respectively 15 per cent. and 10 per cent. The Rhenish Weaving Mill for Furniture Covering, Barmen, shows net profits for last year of 615,089 marks, against 360,255 marks for the previous year and dividend respectively 17 per cent. and 15 per cent., against none and 8 per cent. for 1914 and 1915.

VISCOSITY AND CONSTITUTION AND LUBRICATING OILS.

THE average man troubles little about the exact constituents and the potencies of a complex medicine, a paint or an oil, because he feels that the information the expert might impart to him would probably not make him much the wiser. But he expects the expert to know and he is not pleased, when the expert himself has to admit ignorance. For he may rightly suspect that he cannot rely on the quality of his product and that he may be made to pay excessively for the efficacy ascribed to certain ingredients, which may be absent or really of little value. All this applies strongly to lubricants. At present the oil supply is seriously restricted, oils are expected to do duty under extreme temperature conditions, high prices, possibly fancy prices, are charged, and the expert states viscosity, density, etc., but does not guarantee any performance. When the engineer looks for guidance in text books he finds contradictory information, and when Dr. A. E. Dunstan, F.I.C., and Dr. F. B. Thole brought the "Relation between Viscosity and Chemical Constitution of Oils" up for discussion at the meeting of the Institution of Petroleum Technologists on April 16, they introduced their paper by the remark that profound ignorance still prevailed as to the chemistry of the high-boiling components of petroleum, though the most important properties of such oils, viscosity, "oiliness" and "gumming propensities" depended on the nature of these compounds. This ignorance is due to the difficulties of the problems much more than to neglect of research; the trouble is that oils are too oily, too ready to intermix and to share properties, too much opposed to differentiating.

The high-boiling fractions of petroleum are certainly very complex and far richer in unsaturated hydrocarbons of compositions from C_nH_{2n} down to C_nH_{2n-8} than in saturated paraffins C_nH_{2n+2}. Mabery isolated a few of these compounds from crude American oils; Engler converted amylene and hexylene by heat and pressure into products rich in naphthenes and resembling Baku cylinder oil; Sabatier and Senderens obtained products resembling lubricants by the catalytic action of nickel on acetylene. But in no case, Dr. Dunstan stated, had the chemical constitution of a component of lubricating oils been established. There were some saturated and more unsaturated hydrocarbons (possibly open-chain, more probably naphthenic or polynuclear, but not paraffinoid), and to a small extent aromatic compounds, and further compounds containing sulphur and oxygen. These latter resinous compounds had been isolated by Holde by treatment of the oil with alcohol and ether; they were probably responsible for the gumming which did not occur after the removal of the resins. Agitation with concentrated sulphuric acid removed a good proportion of unsaturated compounds; in the further presence of formaldehyde or of methylal $[CH_2{\cdot}(OCH_3)_2]$ the so-called formolites of Nastyukov and of Heer fell out. But the statement that the remaining oil should be richer in hydrogen was not confirmed by Dr. Dunstan, nor by Mabery and Mathews, and Nastyukov questioned the statement by Marcusson that the remaining oil contained the essential lubricating constituents. There was thus much divergence of opinion—the names mentioned are those of chief investigators—but the suggestion of Schneider and Just, that lubricating oils were colloids opened up important considerations.

In their own researches Drs. Dunstan and Thole first determined the viscosity of the oils and its temperature coefficient by means of the Ostwald apparatus [which consists of a bulb joined by a capillary tube, the whole forming a U or an H], expressing their results in absolute units. The viscosity would depend upon the molecular structure and arrangement, and thus upon the molecular weights, which might vary from 16 up to several hundred. Mineral lubricants being refined petroleum hydrocarbons, the three constitutive variables were unsaturation, conjugation and symmetry. A lubricant should have low viscosity, high lubricating power, and great stability. The viscosity should be low, to prevent needless absorption of energy and heat generation by internal friction. On the other hand, the oil should possess what was designated "body" or oiliness, a property probably connected with viscosity and with capillarity. Very little was known about the surface tension of lubricating oils. Oil having a lower surface tension than metal would spread over it, as would water; but the water film—of greater surface tension than oil, but of very low viscosity—would be squeezed out. Oil formed a thicker film, the important property of which might be adhesion or film strength, the resistance which the oil opposed to rupture. That property did not always go together with viscosity; for solutions of sucrose and of glycerol possessed high viscosity, but were useless as lubricants. Unfortunately there existed no mechanical testing machine for determining the lubricating power. Dr. Dunstan mentioned that he is now experimenting with a very simple device, a capillary glass tube, by the aid of which he can determine the viscosity and, from the weight of the falling drops, also the surface tension. The apparent connection between oiliness and high molecular weight, he pointed out, would support the suggestion that lubricants were colloids, or rather iso-colloids, *i.e.*, polyphase systems in which the disperse component (the colloidal particles) was of the same nature as the dispersion medium (the liquid in which the particles are suspended). In a sense water was one of these colloids, inasmuch as water was supposed to contain, not only molecules H_2O, but also molecules $(H_2O)_n$, where n might be 2 or 3 (di- and trihydrol). If lubricating oils were iso-colloids one could understand the hysteresis effects observed in heavy oils, and the fact that at higher temperatures all the high viscosities of the oils dropped rapidly, finally in all cases to very low values. It is interesting in this connection that Dr. Dunstan has actually been able to observe the colloidal particles with the aid of a parabolic substage condenser of his and of the ultramicroscope. He places a drop of liquid in a little hollow (made in a glass plate) underneath the condenser, and illuminates the liquid from below through the glass. When the liquid is water the field remained dark; in the case of oil, images of the particles are produced by diffraction, and he estimates that the oil particles would have a maximum diameter of 0·03 mm.

As regards stability and durability of the oils, a high percentage of inert paraffinoid hydrocarbons would be preferable to the presence of unsatu ated compounds which were more likely to react chemically and to change; but the former had little lubricating value, though Dr. Dunstan did not mean to imply by that statement that they are of no use in lubricants. Lubricants are mixtures which are to possess a variety of properties which can apparently be secured only by using mixtures. When, however, the unsaturated compounds of an oil were removed by treatment with sulphuric acid or by some other treatment, Dr. Dunstan found the remaining oil had a smaller specific gravity and a smaller viscosity than the original oil, throughout the whole temperature range, though the viscosities approached one another at high temperatures. Dr. Dunstan prefers—with other scientists—to plot the logarithms of the viscosities (rather than the viscosities themselves) against temperature, because the curves then practically become straight lines over a wide range of temperature; these logarithmic curves of the original and the treated oils tended to intersect. Together with Dr. Thole he also conducted elementary analyses, difficult to perform, of the original and the treated oils, in order to determine the ratio of carbon to hydrogen, and he further determined the molecular weights by observing the freezing-point depression of pure naphthalene. Though this latter method when applied to mixtures (as distinct from pure substances) can only yield average results, the figures clearly showed that the resulting hydrocarbon (deprived of most of its unsaturated constituents) had a higher molecular weight. From these various tests and further the iodine and bromine values they finally conclude that a lubricating oil should contain a certain proportion of unsaturated compounds, and that this proportion should be as large as was compatible with moderate liability to reactivity in general, oxidation, polymerisation, gumming; dilution with saturated hydrocarbons would not assist lubrication, but would interfere with the display of chemical activity. The physical condition of the lubricant should be colloidal; that again would point to the importance of the unsaturated compounds, since unsaturation and complex association generally go together. It is very striking that no lubricating oils have, so far, been synthetised, though Krämer and Spilke and Engler (already mentioned) have made some promising researches.

One practical consequence of this investigation was pointed out during the discussion by Mr. Anfilogoff. Too much attention is being paid to the pale colour of lubricants; the colourless condition is secured by the plentiful use of strong sulphuric acid which removes the unsaturated compounds, some of which are certainly essential. What really constitutes oiliness and on what lubricating power depends, remains obscure. Mr. Butterfield quoted a remark to this effect which Mr. C. V. Boys made in his presidential address to the Physical Society last February. Vapour tension, boiling point and surface tension are undoubtedly concerned; certain official tests rightly insist that the lubricant should have been kept at low temperature for some time before being tested. Why the more slippery animal and vegetable oils are on the whole superior as lubricants to mineral oils is not understood. Dr. Dunstan and Dr. Thole have so far chiefly studied mineral oils; but they did observe that the excellent lubricant sperm oil, which chemically stands apart from most lubricants, has a low temperature coefficient of viscosity. Lubricants are used at high pressures and temperatures, but are not tested under these conditions, for want of suitable apparatus. Thus, further mechanical and chemical researches are needed; but colloidal investigation should

strongly be urged too. It would no doubt benefit the problems of lubricants as it has been of vast service in the rubber, silk, textile and pottery industries.

NOTES.

BRITISH FABRICATED SHIPS.

FURTHER information is available regarding what is termed "fabricated ships" for the British merchant service. This name is applied to vessels, the component parts of which are put together and, as far as possible, riveted in bridge building and other inland steel constructional works, the units being as large as is admissible for transit by rail or road to ship-assembling yards, for putting together for launch and completion. The idea of the fabricated ships is somewhat erroneously considered to be novel, but it is really only a development of a procedure which has been adopted in ordinary shipbuilding yards for a considerable time, and has, in the last year or two, been greatly extended, sections of decks, as well as framing, &c., being completed on staging close to the ship, where the work of riveting is done more quickly, because there is greater accessibility for the pneumatic and other riveting machines. No doubt, in our present emergency, advantage accrues from utilising plant at the bridge-building establishments, but the congestion on the railways necessitates the shortest possible length of transit from the steel constructional works to the ship-assembling yards. This is a question which, we fear, is not receiving the fullest consideration, owing in part to the preconceived idea that fabricated ships should be built in specially-devised ship-assembling yards, and particularly in the National shipbuilding yards now being organised on the Bristol Channel. If the component units of ships are prepared in Glasgow, obviously it would be better to utilise them in the Clyde shipbuilding district; this applies similarly to the North-East Coast. The South Wales steel district, therefore, should be the only source of supply for the National yards on the Bristol Channel. Only on this hypothesis is the establishment of National yards on the Bristol Channel, at the present juncture, justifiable. This is particularly the case, as there has been no satisfactory reply, with full evidence, to meet the contention that all the berths in existing yards are not continually occupied, and that all the skilled labour drawn from the army at home which could be absorbed efficiently in private yards has not been supplied to these establishments, already effectively organised and satisfactorily equipped from a mechanical standpoint. The information available regarding the fabricated ship is to the effect that it is a bigger ship than most of the standard ships, and that there is not a curved frame in it. The size and weight of the unit of construction are limited, so that transport is easy, and powerful gear for placing it in position unnecessary. As regards machinery, geared turbines have been adopted in place of reciprocating engines as these can be built extensively in other than marine engineering shops.

ELECTROLYTIC IRON AND NICKEL-IRON.

The electrolytic preparation of pure iron is by no means so simple as is often assumed. When organic acids, citric or oxalic, *e.g.*, are added to the bath, as is frequently done to improve the galvanic deposits of metals, carbon is found in the iron. When all other impurities are successfully excluded, hydrogen and hydroxyde are not absent. The difficulty is that under ordinary conditions both iron and hydrogen are deposited from aqueous iron solutions, the equilibrium potential of hydrogen with respect to pure water being −0.41 volt, and that of iron in normal solution of $FeSO_4$ being −0.46 volt. Hence, argues Professor R. Kremann—who has since 1913 been presenting papers on the electrolytic preparation of metals and alloys and on their metallurgraphic investigation to the Vienna Academy—the electrolyte becomes depleted of hydrogen ions in the immediate neighbourhood of the kathode, and hydroxyl OH is deposited with the iron, that is to say, the iron deposit contains both hydrogen and oxygen. To prevent this, the electrolysis should be conducted in hot and in concentrated solutions, preferably of iron chloride, which is more soluble than the sulphate; for working at lower current densities, the solution might also be acidified, when the current yield would be lowered, however. As regards the hydrogen, in particular, we have to distinguish between the hydrogen gas discharged and the hydrogen dissolved in the iron, and Kremann and H. Breymesser show that, to keep the hydrogen percentage in the iron low, the gas pressure of the hydrogen should be high, not low. Electrolysing in a small boiler, able to bear a gas pressure of 25 atmospheres, they found that their iron contained 0.038 per cent. of hydrogen when deposited at ordinary hydrogen pressure and only 0.015 per cent. when the hydrogen gas pressure was 20 atmospheres. The difference is small, and ordinary analysis would probably not have detected any hydrogen in the iron at all. They oxidised their iron with oxygen and determined the 1 or 2 milligrammes of water formed by this combustion of about 2 gramme of iron; a special determination of any oxygen present was not attempted, apparently, and we do not know how it could have been performed. Hydrogen is generally supposed to render the electrolytic iron hard and brittle, especially on the kathode side; Kremann inclines to the view—from this and many other experiments with iron of much higher hydrogen contents—that the brittleness does not directly depend upon the presence of hydrogen, but rather upon a certain structural arrangement to avoid which the bath should be hot (75 deg. C.) and neutral. There is no special mention of the part possibly played by oxygen in this connection; the point may be reserved for further study, for our knowledge of the influence exercised by occluded gases upon metals is generally unsatisfactory in spite of many researches. In previous experiments with baths of ferrous sulphate and magnesium chloride, to which glycerol had been added in various proportions, Kremann had obtained some deposits which were hardly metallic, as they contained the two metals and their oxides, and up to 2 per cent. of hydrogen and 5 per cent. of carbon; the iron sometimes proved pyrophoric, both when rich in magnesium and when quite free of it, and the pyrophoric character seemed to be connected with the carbon percentages (from the glycerol). As regards nickel-iron alloys, Kremann tried to obtain a higher nickel grade by various ways, also by increasing the hydrogen gas pressure to 25 atmospheres; but he was not successful. When ferrous sulphate and nickelous sulphate are mixed and electrolysed, the alloys deposited are poorer in nickel than the bath, and they are, moreover, brittle. This Kremann could not improve; the two metals do not appear to alloy properly when deposited together.

ABSORPTION AND PHOSPHORESCENCE.

According to the law of Stokes the radiation energy absorbed by a substance is re-emitted, as fluorescence or phosphorescence, at a smaller velocity or greater wave-length. Recent workers in America believe that they have discovered exceptions to this law. Dealing with the closely allied, but often divorced phenomena of "Absorption and Phosphorescence" in his Royal Institution discourse, on April 12, Professor E. C. C. Baly, F.R.S., of Liverpool, said that, like Continental investigators, he did not distinguish between fluorescence and phosphorescence, because there was no demarcation line, and that the exceptions to the law of Stokes were only apparent. The absorption bands were broad, and the law had to be referred to the central portion of a band. Plotting the intensity of a band against the wave-length (as abscissa) he showed that the absorption band and the phosphorescence band each had the shape of an inverted V; the two V's overlapped at their bases, but the maximum phosphorescence was always on the red side of the absorption. For reasons which will presently become clearer, Mr. Baly pays particular attention to the infra-red, which most workers have neglected, and for these studies he makes use of a spectrometer which has a rock salt prism, but only mirrors in the place of lenses; his other chief instrument is a Hilger spectrophotometer. Examining the V bands (or groups) he found that the ascending and descending branches of the V really consisted of a series of smaller V peaks (sub-groups), culminating in the apex, and that the subgroups could further be resolved into lines. When the temperature was lowered, the lateral subgroups gradually disappeared, leaving only the central portions. Organic compounds, which were richer in bands than inorganic bodies, showed like the latter their fluorescence under kathode bombardment (they had to be cooled then, to avoid decomposition), but were more conveniently studied in vapours and in solutions, when their colour often changed with the nature of the solvent and the character (acid, neutral, alkaline) of the solution. These changes had been ascribed to changes in constitution—especially when compounds of colourless constituents assumed different colours under different conditions—but there was only a change in the vibration period. Determining the difference in wave-numbers (reciprocals of wave-lengths), *e.g.*, in the three main groups of β naphthol, Professor Baly found constant differences between the groups, in absorption and in phosphorescence; again, he observed constant, smaller differences between the subgroups, and again smaller differences between the lines of the subgroups. In the case of sulphur dioxide the subgroups yielded the differences 11.79, 22.32, 35.32, the lines the differences 2.73, 4.32, 8.18. Now $2.73 \times 4.32 = 11.79$, &c., and the product $2.73 \times 4.32 \times 8.18$ was 96.43, which was the basis of the whole absorption spectrum. All the wave-numbers, moreover, appeared to be integer multiples ($n = 10$, 12, 19, 23, 26, &c., in examples given) of a fundamental vibration in the infra-red. Professor Baly supported his arguments by many other striking figures of constant differences, exemplifying further the connection between the spectrum basis of a molecule (SO_2) and those of the constituent atoms (S,O) or of a compound (phenol) and those of its radicles (benzene, water). Residual valency in his view would be something akin to degrees of freedom of vibration, and the repetition of the fundamental frequency in multiples would look like a natural consequence of the quantum theory. It sounded all very convincing. But Dr. Baly has to correct his figures for solvent and concentration, and one has a lurking feeling about these and similar hypotheses that, once the quantum theory presumed—Baly accepts Bjerrum's formula for the connection between vibration frequency and rotational frequency of the atom—those constant differences may not amount to much more than algebraical gymnastics. Yet Professor Baly certainly predicted some of his regularities, and the considerations conform with his view. But there are electromagnetic fields of force in the atoms which are condensed on combination and opened up in stages by the absorption of light and the action of solvents, and that reactivity depends upon these forces.

TREADLE LATHES ORDER.—By an Order of the Minister of Munitions dated April 15 no treadle lathes of 3-in. centres or over, for use in cutting or working metal or wood, may be bought or sold without a permit. Applications for permits to buy should be made to the Executive Officers of the Area Clearing House Board, whose addresses may be obtained from the Director, Central Clearing House, Ministry of Munitions, Charing Cross Buildings, W.C. 2; and for permits to sell from the Controller of Machine Tools at the same address.

MICA.—The Minister of Munitions, in exercise of the powers conferred upon him, orders as follows: (1) No person shall as from the date hereof (the 15th inst.) until further notice purchase or take delivery of any mica situated in the United Kingdom, or sell or deliver any such mica to any person other than the holder of a licence and in accordance with the terms thereof, and (2) No person shall until further notice use any mica for the purpose of any manufacture or work except under and in accordance with the terms of a licence issued under the authority of the Minister of Munitions. (3) All persons shall send to the Controller of Non-Ferrous Materials (MS/R), Ministry of Munitions, 8, Northumberland-avenue, W.C. 2, returns with regard to their stocks, purchases, sales and deliveries of mica, and any contracts or orders made or given to or by them requiring for their execution the use of mica as shall from time to time be required by the said Controller of Non-Ferrous Materials. (4) All applications for licences under this Order shall be made to the said Controller of Non-Ferrous Materials and marked "Mica Licence." (5) The expression "Mica" shall mean block mica of the following quality and size grades: Clear and partly stained "Ruby" of "best" or "Government standard" quality, or suitable for use in the manufacture of magneto condenser plates, in size grades No. 3 to No. 6, inclusive, or their equivalent in rectangular or other trimming, and shall include mica coming within the above definition when split from block of any quality. (6) This Order may be cited as the Mica Control Order, 1918.

LITERATURE.

The Principles of Iron Founding. By RICHARD MOLDENKE, E.M., Ph.D. London: Hill Publishing Company, Limited. [Price 17s. net.]

THE name of Richard Moldenke is as familiar to foundrymen in England as it is in America. He is an example of that rare combination—the intensely practical man, possessing the highly trained technical knowledge which has been developed by the study of first-hand conditions, supplemented by travel. Equipped with a university training, he has occupied a Chair of Engineering at one of the American mining schools. He has made nearly a quarter of a million tons of castings, turning out at one period about 50 tons a day. He is the highest authority on malleable cast iron, and is the secretary of the American Foundrymen's Association, which holds its conventions annually.

The book before us is modestly offered by the author as a work of reference, compiled from his observation and experiences, and he deprecatingly admits that "there is still so much to learn." He does not rank it as a hand-book, but as a "study of the things upon which hand-books can be built." Throughout, he deals with the important basic principles and essential elements, rather than with details. There is no example of a foundry mould in the book, no detailing of furnaces and plants. General foundry practice is to be dealt with in a second volume. This volume is occupied chiefly with the metallurgy of iron, foundry materials and melting processes. These technical matters are prefaced with an interesting historical sketch, and with chapters that concern the business side of foundry work. The historical introduction deals at considerable length with the growth of the industry in Germany, whence that of Pennsylvania was derived. Lutheran and Moravian settlers fleeing from persecution brought their stove plates with them. When these plates, which were adorned with biblical subjects, became broken or worn out they took them to the nearest blast furnace to be recast, and this was the beginning of the vast development of the American stove business. The first blast-furnace was erected at Lynn, Mass., in 1645. The cupola was not introduced until 1820. Several pages of these early records are worth reading.

The second chapter, the "Relation of the Foundry to Manufacturing Enterprise," gives occasion to some caustic observations. The writer insists on first-hand knowledge of everything that concerns the business, including visits to the blast furnaces which supply the foundryman with pig-iron, and to the regions whence the supplies of coke or coal are derived. With reference to the enormous quantity of machinery now installed, he says that "the road to cupolas is paved with moulding machines. Conveying systems and machinery, &c., will be found in many a scrap pile." The magnitude of the industry is reflected in the statement that about 10,000,000 tons of gray, malleable and steel castings were made in 1916 in the United States and Canada, which means that about 12,500,000 tons passed through the cupolas and furnaces in 6,300 foundries. This enormous product has an immense influence on the financial condition of a country, and on national prosperity, for it involves big problems involved in freight, in the transportation of pig-iron, sand, and finished castings. In considering the employment of machinery the author's views are rather conservative. The relation between the cost of the machines, and the labour saved by their use must be well weighed, since machines cannot be run without labour. As a rule it is better to employ labour, with good mechanical equipment for handling, transport, &c., than to invest in machinery that eats up interest during slack times. Sinking heavy capital may prove a costly mistake. Mr. Moldenke urges the need of specialising in the foundry, so that stock may be worked on in slack times without causing anxiety as to the future disposition of the stock. In this connection he is in favour of operating a foundry continuously in preference to enlarging an existing plant. This, however, is only possible with specialised products. He hints at a solution of the difficulty of making moulds with sufficient rapidity to keep the cupola always running, in a larger use of the jar-ramming machine, and in the improvement of the permanent mould, or of some kind of "long-life" mould, this repetitive work to be taken from the skilled men, who may be employed to better advantage elsewhere.

Chapter III, which treats of the "Organisation of a Foundry Enterprise," contains suggestions which in general would apply to all businesses. Thus, whoever wishes to embark in foundry work must know all there is to be known about it. There must be capital, and a market. The aim must be to produce only high-grade work, to be sold at top prices. There must be the fixing of individual responsibility from top to bottom, the recognition of the human element, the advancement of efficient men trained in a firm's service, rather than to seek men outside. For, then the organisers will "not have to pull up short after every foundry tramp of the country has passed through the shop, foremen have been lost and changed, and the shop generally run down."

Chapters IV to VI cover familiar ground, and occupy between a third and a fourth of the volume. They comprise an "Outline of Iron Metallurgy," an "Outline of Iron-making Processes," and the "Properties of Cast-iron." Though these embody much that is well known, yet they are worth reading, because facts and statements are illuminated by the keen observations of a man who knows the things at first hand, and who gives results of his personal observations and valuable experiments. He is, above all, eminently practical. Though he gives sketches of the micro-structure of castings, he says that "the foundryman is not particularly interested in these, since a casting in the gray iron foundry—once made—cannot be changed by subsequent treatment"—as steel may be by heat treatment. "The microscope," he says "will probably find its application in the foundry laboratory solely for the purpose of investigation and study—'after the fact'—and not before." The combinations of iron and the usual elements are stated, and the varying influences which these exercise on the product. The evil effects of oxygen, and the unavoidable presence of some residual oxygen in iron are discussed, and the author's experiments on this subject are given. And they reveal the reason of facts which are known to foundrymen of experience. Thorough melting, white-hot iron, with plenty of life, is insisted on, even though the iron should have to be poured into heavy moulds at a much lower temperature "dull," with little fluidity. This is a far better practice than allowing the metal to remain in the cupola, where it is exposed freely to the presence of oxygen. Oxidised iron sets quickly, and internal shrinkage strains result, and sponginess and draws in central parts. The condition is one which will cause an increase in the proportion of combined carbon with consequent hardness and brittleness, and the formation of gas bubbles in the casting. The author regards the use of deoxidizers such as titanium as of less value for the prevention of this evil than the employment of proper melting methods, and the careful selection of pig-iron.

Chapter V, an "Outline of Iron-making Processes," passes in brief review the direct wrought-iron process, that of the blast-furnace, the indirect wrought-iron process, conversion by cementation, by the Bessemer, and the open-hearth processes, and the electric furnaces. Chapter VI, on the "Properties of Cast-iron," is one of special interest to the working foundryman, because it explains the reasons of many phenomena which he observes in the course of his labour. The researches of Mr. Outerbridge on the growth of cast-irons under repeated heating and cooling furnish the explanation of the fact that a coarse, open-grained, high silicon and graphite iron is about the last thing to use for heat-resisting castings, as annealing pots, and chills, for which mottled iron alone is suitable. Another matter of daily routine concerns the charging of different irons in the same cupola, these being ranged in superposition in the order of their melting-points. When steel scrap is used this should go first on the fuel, the pig next, and the sprues on the pig-iron. Harder pig-irons (white, or mottled) go over the softer gray pig-irons, and heavy scrap with pig-irons. The melting will then be completed at about the same time. The result of the author's investigations on the melting-points of pig-iron show the white irons melt between 1,990 deg. F. and 2,070 deg. F., and the gray irons between 2,260 deg. F. and 2,280 deg. F., a total range of 290 deg., other irons falling between these extremes. The reason why a molten gray iron can be held much longer in the ladle than a white iron is, that while the melting and the freezing points of the latter may nearly coincide, the freezing-point of a gray iron will be much lower than its melting-point. This fact, taken in association with the superheating which can be effected in the cupola, perhaps from 200 deg. F. to 300 deg. F., becomes of great value in the foundry when metal has to stand in the ladle for considerable periods, as during relays of tapping into a large ladle, for a big cast, or during transportation, and again for the purpose of pouring dead metal in heavy masses, but metal which must have been melted fluid and hot in the first place.

This chapter on the "Properties of Cast-iron" is one which is rich in suggestive matter to the man who makes castings. Sections which teem with subjects of daily interest are those on "Fluidity," "Grain Structure," "Porosity," "Chill," "Hardness," "Shrinkage," "Strength." Burning-on is shown to be possible in consequence of the plastic condition assumed by gray iron just before it melts, at which point graphite begins to go into solid solution in the iron. Mr. Moldenke believes that this old method is more reliable for heavy work than the oxy-acetylene flame, because the heat is not so local, and therefore resulting strains are not so liable to cause subsequent rupture. Under the "Grain Structure of Cast-iron" the effects of the setting of the colder metal in a mould are discussed. The cooling due to the distance which the metal has to travel from its point of entry, and to the hotter and colder sand against which it beats, with consequent unequal times of setting, the results of feeding, the freezing-up of gates, and the desirability of pouring the heavy parts of castings, of which the flywheel is typical, through many gates around the rim on the top, thus rendering risers unnecessary. Again, the proportion of silicon present is a vital element in very rapid, or slow-cooling, producing a white, or a gray casting respectively. Then this leads to the consideration of the cry of the machinist for "soft castings," or those of gray, graphitic iron. Since these are not strong enough for many specifications, the difficulty is surmounted by adding a low carbon steel scrap, the result being castings of low total carbon content, most of which is in the form of finely divided graphite. The control that is exercised on the crystallisation of certain parts of castings gives occasion to remarks about artificial cooling of portions other than by the chilling process. One method is that of water cooling, formerly used for cast-iron guns, and of value still in other work if due attention were devoted to it. As an alternative the author recommends the introduction of heavy masses of cast-iron into the moulds in close proximity to the surfaces where fine grain is required, in order to withdraw the heat rapidly through the comparatively thin layer of sand or loam between the masses and the molten metal. The section on "Chill" returns to the subject of the influence of silicon, which, after carbon is the most influential element in the metallurgy of cast-iron. Doses of silicon in greater or less degree will control the proper composition of a white or a mottled pig-iron that is giving too little, or too much chill. But phosphorus, sulphur, manganese, though of secondary influence, may have to be limited, since otherwise they are likely to interfere with the silicon-carbon effects. A chilled section should not show an abrupt line of separation from the gray interior body, but there should be a trans tion zone of mottled iron. In the section on "Hardness," meaning in cast-iron that which is due to the presence of combined carbon, results are shown to be mainly dependent on the regulation of the proportion of this allotropic form. If this runs below 0.75 per cent. a casting can be machined readily. At 1 per cent. the operation becomes difficult, and at 1.50 per cent. practically impossible. But the form in which this may be present is vital. As Austenite the proportion 0.8 would render the casting so hard that it could not be touched with a file, but if in the form of

cementite it can. Here the Brinell ball test is recommended for regular foundry use, as a means by which systematic selections from the day's work can be checked.

In the section on "Shrinkage," the distinction is drawn between the linear difference in the size of a casting and its pattern—"contraction," and the difference in volume-"shrinkage"—terms which have been used loosely to indicate either phenomenon. Since the setting of metal takes place from the outer portions next the mould inwards, little by little, and since stretching must take place, which if in excess results in void spaces, or even in rupture, a sound homogeneous casting in the ideal sense is an impossibility. This opens questions concerning the practice of "feeding" or "pumping," to supply fresh, hot metal to take the place of that which is shrinking and congealing, and to churn up the iron that is becoming stagnated. "Segregation" and the formation of crust is next treated. Under the section "Strength," the weakening effect of graphite is emphasised. The author says that the very fact of its presence in a casting is "a direct invitation to breaking down when strain is applied. Given the starting point of a crack, and fracture soon follows. Every flake of graphite represents a crack in a casting." Again, "it is practically impossible to predict the strength of a cast-iron from a given composition. All that can be given is an approximation, and, in fact, the best results are obtained when a foundryman builds up his own table of strengths, as his daily practice furnishes him the data to do it with." Here a table is compiled of a large number of specimens of cast-iron by various experimenters, with chemical compositions, and corresponding tensile strengths, with the observation, "The hopelessness of predicting the strength of a cast-iron from its composition will be apparent from these results." The general effects of varying percentages of the elements present are discussed. The author prefers to take the transverse strength of iron rather than the tensile test as the basis of its practical utility. The other stresses—compressive, shearing, impact, alternating, resilience—are briefly considered, and then we get back to the old precautions, as, careful designing, the avoidance of sharp corners, and of great inequalities in sections, a good factor of safety, and finally the seasoning of castings. "Resistance to Corrosion" is a useful section, as also is that on "Resistance to Friction."

Chapter VII on the "Classification of Castings" must be accepted with the caution just now given, as furnishing analyses which, while useful as pointers, may be varied considerably. The whole range of work is gone through, with typical percentages suitable for each of silicon, manganese, sulphur, phosphorus, and total carbon. The groups range alphabetically from "acid-resisting castings" to "white iron castings," a total of 48 classes of work. And since the rate of cooling plays so important a part in the controlling influence which silicon exercises on the retention of combined carbon, or its separation as graphite, the proportions are modified in many of these analyses, for "light" "medium" and "heavy" castings. Valuable critical and elucidatory remarks preface the various mixtures.

Chapter VIII deals at considerable length with the subject of "Foundry Raw Materials," the pig-irons, scrap, and so on, being treated critically. It teems with information, the fruit of a rich experience. The use of ferro-alloys is not generally recommended, the selection of suitable pig-irons in the first place being preferable. The same remark applies to deoxidisers. "Fuels" and "Fluxes" have sections allotted to them, and these are followed by the "Refractories"—sand, fireclay, moulding sand. In connection with the last, the various requirements that contribute to the making of a perfect mould are stated, providing a lengthy commentary on the author's definition of an ideal moulding sand—"a sand consisting of uniform-sized, rounded grains of silica, each grain evenly coated with the thinnest necessary layer of the most refractory and fattest clay to be had." Analyses of many sands are given, and the sizes of the grains when passed through standard sieves, to arrive at the average fineness. Physical tests are noticed, as strength, the tempering with water, and venting capacity. The core sands follow, the blackings, the mineral facings, parting sand, core binders, &c.

Chapter IX, on the "Technology of Combustion," contains a scientific treatment of this subject, leading up to the next chapter, which deals with the practical work of "Melting Processes." Here the cupola is first treated at considerable length in its various details of construction and in the methods of its operation. Though much is familiar, common facts are invested with a new interest under the illuminating observations of the author. The numerous cupolas by different manufacturers are not illustrated—space is rather devoted to the principles on which their variations are based. Chapter XI is a continuation of "Melting Processes," but its subject-matter is the air furnace and its work. The open-hearth and the electric furnace are touched on lightly. Chapter XII, on "Mixture-making," should be studied in connection with chapter VII—The "Classification of Castings." That gave typical percentages of metal, this deals with the daily practice of the foundryman who has to use his judgment in selection from such stocks as may happen to be available. The author says that once, in the absence of pig-iron, he ran three days on scrap alone. When scrap is cheap, the temptation to use more than the maximum 40 per cent. is great, but the result is a mounting up of the sulphur content, absorbed from the fuel at each remelting, until it increases to a dangerous total. The action of the several elements present in pig-iron is stated in turn, and directions are given for their due regulation. But we come back to the necessity for experience, and sound judgment. "After all, however," says Mr. Moldenke, "in addition to the simple figures which ensure actual melting results, a lot of judgment must be exercised if castings are to be made without having the yard a curiosity shop in irons."

Chapter XIII, "Testing Cast-iron," includes, in addition to the foundry-shop tests for strength, analyses of iron and of coke. Only the transverse test for bars is of use for daily practice. Pouring the test bar on its casting, as so often advocated, instead of separately, is strongly discountenanced, for reasons which when stated are seen to be excellent. The shrinkage is different in the smaller bar and in the larger sections of the castings. It will vary with the position of the bar; on the top, the middle, and the bottom different results will appear. Regarding the use of the microscope, Mr. Moldenke again points out that the heat treatment so necessary for steel cannot be applied to cast-iron. "No one pretends to go into the foundry with this instrument, and bring about a practical result." The pyrometer, the X-ray apparatus, the spectroscope, the electric furnace, are of no practical utility in the foundry. Only "a little of the speculative . . . is to be recommended to the foundry investigator. It keeps him in love with his work, and spurs him on to a keen observation of the minutiæ appearing now and then in the development of new phases of old processes. He will not then regret the day that brought him in touch with that most serviceable, curious, and still little understood conglomeration of elements, called cast-iron."

A short glossary of foundry terms, and a useful appendix dealing with methods of analysis, and an index, complete the volume.

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The Strength of Ships. By J. BERTRAM THOMAS, Assoc.M.Inst.C.E. London: Scott, Greenwood and Son. [Price 5s. net.]

Aeronautics in Theory and Practice. By W. L. COWLEY, A.R.C.Sc., D.I.C., and H. LEVY, M.A., B.Sc., F.R.S.E. London: Edward Arnold. [Price 16s. net.]

Concrete Cottages, Small Garages and Farm Buildings. By ALBERT LAKEMAN, M.S.A., M.C.I. London: Concrete Publications, Limited, 4, Catherine-street, Aldwych. [Price 5s. net.]

The Best Book on Gardening. London: Temple Press, Limited. [Price 1s. 3d. net.]

HONOURS FOR NAVAL ENGINEERS.—The *Supplement to the London Gazette*, dated the 17th inst., announces that the following honours have been awarded, with the approval of His Majesty the King, to members of the engineering branch of the Navy, among others:—For services in mine sweeping operations between April 1 and December 31, 1917: Engineer-Lieutenants John Black, R.N.R., and W. S. Archibald, R.N.R.; Engineer Sub-Lieutenant Wm. Brown, R.N.R., and Acting Artificer Engineer R. H. Thomas, R.N. To receive a Bar to the Distinguished Service Cross: Chief Engine-room Artificers Andrew Berwick, R.N.R., and W. R. Lane, R.N.R.; Engine-room Artificer H. G. Waldron; and Enginemen A. E. Arnold, R.N.R., R. Boak, R.N.R., C. W. Carter, R.N.R., T. R. Clementson, R.N.R., John Donald, R.N.R., J. W. Ethell, R.N.R., C. F. Mansell, R.N.R., J. W. Liddle, R.N.R., Harry Smith, R.N.R., and Harry Taylor, R.N.R. To receive a Bar to the Distinguished Service Medal: Engineer-Lieutenant J. B. Finney, R.N.R.; Warrant Engineer Ernest Brinham; Acting Artificer Engineer Frank Meachem; Chief Engine-room Artificer G. L. Murray; Enginemen J. W. Bryan, R.N.R., G. H. Johnson, R.N.R., Fred. Jones, R.N.R., W. R. Porter, R.N.R., H. E. Pughe, R.N.R., W. H. Quaggan, R.N.R., N. L. Reddy, R.N.R., and Alex. Smith, R.N.R. For Service in Submarines: To be a Companion of the Distinguished Service Order: Engineer Lieutenant-Commander C. J. Limpemy, R.N. To receive the Distinguished Service Medal: Chief Engine-room Artificer Chas. Mallalieu and Engine-room Artificers John Bruce, R.N.R., A. E. Bullock and F. S. Tilford. Mentioned in Despatches: Engineer Lieutenant-Commanders E. G. Ham and C. G. Breton; Artificer Engineer Fredk. Asker; and Engine-room Artificers Samuel Dolby, W. H. Reed and T. L. Scott. For Services in Action with Enemy Submarines: To receive a Bar to the Distinguished Service Cross: Chief Artificer Engineer Joseph Hawkesworth.

THE LATE MR. RICHARD B. PROSSER.

THE death of R. B. Prosser, on March 26, at his house in Kentish Town, has, it may fairly be said, deprived us of one of our best authorities on the history of invention. Born in Birmingham, 1838, he was the eldest son of Richard Prosser, a mechanical engineer, and inventor of considerable reputation in his time. Amongst the father's successful inventions were included nail and screw-making machinery, rollers for calico printing and the very ingenious machine for making buttons by compressing dry powdered clay, afterwards successfully applied by Messrs. Minto to the production of mosaic tesseræ, and still employed for the purpose. Though many of the inventions were profitable he spent most of the money on the development of others—20,000*l.* went on his method of making iron tubes—and at his death, in 1854, he was by no means well-to-do.

The elder Prosser was an intimate friend of Bennet Woodcroft, the well-known head of the British Patent Office, and it is understood that he advised or assisted Woodcroft in the preparation of the indexes of patentees which were purchased by the Government and formed the foundation of the publications afterwards issued by the Commissioner of Patents. After the passing of the Patent Law Amendment Act in 1852, Woodcroft was appointed, first Superintendent of Specifications, and afterwards, in 1864, Clerk to the Commissioners of Patents, on the resignation of Mr. Edmonds, the first holder of that office. Practically the whole administration of the office was in Woodcroft's hands from the very beginning, and it is to his organising ability that is due the system which, with the necessary development and modifications, has worked well down to the present time. Amongst other useful institutions, Woodcroft, having obtained authority to provide an office where the printed specifications and other publications of the Commissions might be consulted, founded the Patent Office Library. This was opened in 1855. It is believed to be the first library in London open to the public free of any restrictions whatever, and it has now developed into one of the best scientific and technical libraries in the kingdom.

In the following year, 1856, Woodcroft gave the son of his old friend, the subject of this memoir, a post in the library, and here he remained for some twenty years.

Like his chief, Woodcroft, young Prosser had a strong antiquarian bias, and during his service in the library, he devoted himself earnestly to the study of the history of invention. Being naturally painstaking and accurate, he accumulated a very remarkable store of information, and there were few branches of the history of industrial development in this country with which he did not make himself thoroughly familiar. The information he acquired was always at the service of the frequenters of the library—mainly inventors, patent agents and the "searchers" they employed, and journalists, and they appreciated the readiness with which it was given and the accuracy of the knowledge supplied. Prosser not only had the essential librarian's gift of knowing where to look for information, but on his own subject he was an encyclopedia in himself, and a few minutes' talk with him was often more serviceable than an hour's laborious research.

When the 1883 Act necessitated the formation of a staff of examiners of specifications, Prosser, after being for a short time transferred to the Trade Marks Division of the office, became Superintendent Examiner. It must, however, be admitted that his new work was not congenial to him—probably his natural bent was rather that of the historian than of the administrator, and in 1888 he retired.

It is a matter for considerable regret that he never carried out an idea he long had in his mind, the writing of a history of invention. He had accumulated a large amount of material for the purpose, and a good many years ago he discussed with a friend a proposal for the joint preparation of an annotated issue of abstracts of British patent specifications or selected specifications. Had Woodcroft lived a few years longer it is not unlikely that the idea might have come to something, as it was just what he would have appreciated, but as a matter of fact it never got beyond the preparation of a specimen page. In his later years, long before his death, Prosser suffered from partial blindness, and this prevented him from carrying out his long-cherished scheme. That he did not carry it out was a real literary loss. Nobody could be found more competent to write such a book. It would have provided a store of minute and detailed information of infinite value to future historical students and writers.

Both before and after his retirement Prosser did a good deal of literary work, though he never published any book of importance. His "Birmingham Inventors" was a reprint of articles contributed to a Birmingham paper and contains much information not elsewhere available. To the "Dictionary of National Biography" he contributed a number of admirable lives of inventors. At one time he was an occasional contributor to various technical periodicals, and down to the time of his death he was a regular correspondent of *Notes and Queries*.

He served for a time on the London School Board. He took great interest in church matters and was a member of the House of Laymen. He was an early member of the Library Association, though he does not appear to have contributed to its proceedings.

ITALIAN INDUSTRIAL COMBINES.

THE formation of large combines within almost every industrial branch which is being carried on in most countries seems in Italy to have found special favour, the outcome being at least two unusually large and comprehensive combines. First on the list stands the Ansaldo group, which, thanks to the conditions resulting from the war, now comprises steel works, rolling mills, shipyards, gun factories, locomotive works, factories for rolling-stock and motor cars, as well as shipping. There is also the "Ilva" group or company, which was started ten years ago at Bagnoli, near Naples, in order to derive the advantages of special preferences conferred upon new South Italian factories, comprising freedom from taxes for a series of years and a preferential supply of iron ore from the Island of Elba. When, in the year 1911, the heavy Italian iron industry was reorganised, the "Ilva" company secured the leading position within the new organisation, to which also Elba, Terni, Savona, Fersiere and Piombino belong. The "Ilva" concern has, during the war, increased its capital from 30,000,000 lire to 50,000,000 lire, and this latter amount is now about to be trebled. In connection with this last important increase of capital the following programme has been set forth. The Bagnoli works are to be extended and by combination with other concerns made as independent as possible, so as efficiently to support and further the South Italian industry after the war. As regards the supply of raw materials the company has not only the iron ore deposits in the Island of Elba, but also the new iron ore deposits in the Island of Sardinia to fall back upon, which will guarantee an ample and regular supply. In regard to the difficult fuel question, the company has secured a share in the lignite deposits in the upper Arno Valley, and has formed a second concern for lignite extraction. Under these circumstances the "Ilva" company will only require foreign coal for the production of coke for blast-furnaces. Hydro-electric stations will be relied upon for power supply, and in order to be able to secure current on favourable terms the "Ilva" company has become interested in the Societa Meridionale di Electricita, which latter is now enlarging its power stations on an extensive scale. One of the schemes, in conjunction with the "Ilva" company, refers to the electrification of the railways proceeding from Naples. The company already owns a fleet of 60,000 tons, but this is to be greatly increased, for which purpose shipyards are to be erected at Piombino and Bagnoli, which yards also are intended to build for other firms. With a view to guard against any difficulties in the matter of the propelling machinery for their vessels the "Ilva" company, jointly with the Miani Silvestri concern, in Milan, which before the war principally built locomotives and rolling-stock, and which now has increased its capital from 16,000,000 lire to 24,000,000 lire, has founded the Officine Meccaniche e Navali at Naples. At the old works at Bagnoli a fourth blast-furnace has been constructed and a basic steel works built, for which the Sardinian ore is well suited. The basic slag is to be used as manure in the Southern districts of the country.

COAL CONTRACTS.—In view of the probable effect of the man-power proposals on the coal market, all contracts for the sale of coal for export from the United Kingdom, or for ships' bunkers, made on or after April 18, must be limited to a period not exceeding three months from the first of the month following that of the date of the contract.

CRYSTAL PALACE ENGINEERING SOCIETY.—The "Nilson Premium" for the best paper read before this society [affiliated to the Society of Engineers] during the past session, has been awarded to Mr. L. T. Beck, for his paper entitled "Modern Developments in the Cleaning of Blast-Furnace Gas." Other papers read during the session were: "The Cultivation and Manufacture of Cane Sugar," by R. G. Salas; "Engineering Applied to Prestidigitation," by W. G. S. Grimmond; "The Tube Railways of London," by B. G. Simmonds.

THE SHIPBUILDING ADVISORY COUNCIL.—The Secretary of the Admiralty makes the following announcement: The members of the Shipbuilding Advisory Council have individually informed the Admiralty Controller that, whilst they desire to continue to place their services as leading members of the shipbuilding and engineering industry unreservedly at the disposal of the First Lord and the Controller-General of Merchant Shipbuilding, in the furtherance of the output of tonnage, they feel that the existence of a council at this stage may have the effect of limiting Lord Pirrie's freedom of action. They have, therefore, tendered their resignations as members of the Shipbuilding Council. The Admiralty take the opportunity for acknowledging the great debt the country owes to these gentlemen for the valuable advice and assistance they have given during the whole time the council has been in existence, and have gratefully accepted their cordial offer of continued co-operation.

AIR PUMPS.

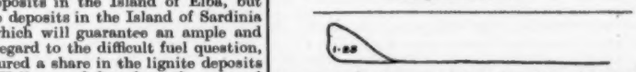
TO THE EDITOR OF ENGINEERING.

SIR,—In my letter published in your issue of October 12, page 395, I dealt with the form of the head of the pump to enable the amount of air leakage to be easily seen. The importance of finding and stopping air leaks can hardly be exaggerated. There are often great difficulties to be overcome in finding them, a few instances may therefore be useful.

In one old steamer the air pump had never been able to maintain more than about 13 in. vacuum. To ascertain if there were any air leaks, a pipe was fitted to the cylinders and led up until its upper end stood well above all parts of the engines and vacuum system; the whole was then filled with water to the top of the pipe.

This test did not show any air leaks sufficient to prevent good results being obtained. However, after the test had been continued for some time, and when all hopes of finding air leaks had been given up, the water was found coming through all parts of the bottom of the low-pressure cylinder. This cylinder happened to be jacketed, in other words had a double bottom, both bottoms were porous but the holes were so small that the water took an appreciable time to get through: in fact, under working conditions it never succeeded for, before the water escaped, a vacuum was again formed in the jacket and thus the water was driven back by the air pressure outside. To remedy this a large plaster, consisting of a thin plate and red and white lead, was applied and excellent results were obtained. This shows the great importance of keeping the test on a long time, some hours at least.

When finished, all the water should be thoroughly drained off and the engines, &c., run to ensure the working surfaces becoming greasy and not liable to rust;



in one case this was neglected and much damage done. A mistake is often made in conducting this test. Engineers frequently shut off all small connections and confine the test to the main condenser; they do it naturally, whereas every connection should be thrown open and included. Also it is necessary to make sure there really is water in all parts subjected to vacuum.

Take another case in which the engines were new and the vacuum bad. The builders would not admit the trouble could be due to air, stating that every casting had been tested to a good pressure and was perfectly tight, and confirmed their statement by pointing out that when the engines were stopped they held the vacuum for an hour or more. This appeared conclusive.

After testing the engines carefully and comparing the results, it was found that the faster they were driven the nearer the pressure approached to that due to the temperature. The inflow of air, if there were leakage, would probably be constant and the quantity extracted would depend on the speed of the air pump. The results obtained, therefore, showed that the trouble was due to air. The water test was now applied; water leaked from nearly all the studs in the low-pressure cylinder cover. The cover having been removed, it was found that the joint had been made with two lamp wicks, one round outside the studs the other round inside, but the inner one had fallen down on to the piston.

When the engines were stopped the low-pressure valve happened to be low down, leaving the top port open, so that when the air rushed into the cylinder it travelled through the port on to the back of the valve, holding it tightly up to its face, and thus preventing leakage past it into the condenser. This proved that although the engines may hold a fairly good vacuum for an hour or more there may be a very bad air leakage somewhere.

It is almost impossible to indicate air pumps correctly under some conditions, *vide* diagram illustrated by your Fig. 2, page 312, March 10, 1889. For convenience I reproduce it here, being similar to many that have been taken.

The diagram is decidedly interesting; it apparently proved that, under the existing conditions, the pump was absolutely useless, as the pressure did not reach the atmospheric line and therefore no air or water could have been discharged. This diagram was taken off a set of three pumps.

Whilst indicating a similar set further light was thrown upon the matter. During the first run this kind of card was obtained and so it was arranged to have a complete set of fresh indicators ready for the final trial. On the final trial, no improvement resulting, one of the indicators was taken off for examination, and, in order to prevent water being thrown out of the pipe, a piece of insertion was placed over the end of the pipe and held down, but caused great surprise by adhering tightly of its own accord. This showed the indicator was not defective and appeared conclusive proof that the pump really was not discharging either air or water; but, upon removing one of the inspection doors and inserting an electric lamp, it was found there was a slight upheaval, due to the discharge of the water, and one or two bubbles of air coming from each valve, showing the pump was working satisfactorily and that the diagram was totally misleading. Diagrams of this description had been repeatedly obtained and had until then puzzled my father.

In investigating these peculiar cards the possibility

of having several inches of vacuum in one end of a pipe and 16 lb. or 18 lb. pressure in the other at the same time appeared out of the question, when the pipe was only about 9 in. long and had a clear bore ¼ in. diameter. It might be thought that the bucket had closed the end of the pipe and so throttled it; but this was not so, the mouth of the pipe was quite free. The same type of diagram had been obtained when the pipe ran vertically straight up through the valve seat to the indicator, so that the bucket had a straight drive up the pipe.

The 16 lb. or 18 lb. pressure referred to is only a moderate estimate, the pressure may have been and probably was far greater as the sticky metal valves had to be lifted, the water between the top of the valves and their guards driven out and then the condensate ejected. The unreliability of the diagram illustrated is further demonstrated by the vacuum in the condenser being over 2 in. more than that indicated in the pump.

This great difference in the pressure at the two ends of a short pipe occurred when the pump was only going 140 r.p.m. and it is worth noting the construction was such that the bucket would be travelling slower when the pump passed over top centre than the bottom centre, thus giving more time for the equalization of pressure.

It seems almost incredible that this difference in pressure could possibly exist, and yet it did, and, in these later days, makes it easier to understand aviators complaining about the air being bumpy and in pockets and the effect of differences in pressure on the movement of their machines making them feel sick.

I am, Sir, yours faithfully,

CHRISTOPHER F. EDWARDS.

"The Poplars," Manor-road, Itchen, Southampton.

THE CANAL QUESTION.

TO THE EDITOR OF ENGINEERING.

SIR,—I sincerely trust that you will continue to expose the fallacy that this country presents a suitable field for canal traffic; and, further, that you will make it clear that the so-called success of waterways in France is due, in large measure, to Government subsidy. The canals there earn nothing, neither for interest, upkeep, repair or amortisation. All charges are borne by the Government, which, further, prevents the railways from active competition with the canals for low-grade traffic.

We have an excellent object-lesson in the part that canals are likely to play here. The Thames is canalised from Richmond to Oxford, and can accommodate barges carrying one or two hundred tons. Steam traction is permitted, since it gives no trouble with the banks as it often does in a canal. The Thames Valley is fairly thickly populated, and demands a large traffic. Yet one may spend a whole day boating on the river and never see a barge in motion. The Great Western and South-Western Railways both conduct a large goods traffic in the Thames Valley on lines which have cost great sums, while the Thames, which was not very expensive to canalise, and which is administered by a public corporation which does not aim at making profits, carries very little except pleasure traffic.

Yours truly,

"PUNTER."

ELEMENTARY ECONOMICS AND THE EDUCATION BILL.

TO THE EDITOR OF ENGINEERING.

SIR,—Mr. Fisher asserts that "no country in the long run suffers economic injury from an improvement in the general education of its population," and *The Times*, on March 18, asserts that "no student of economic history can deny this." Both are bold and unsupported statements. May I submit for consideration a few fundamental truths and the essential relation which education should bear to them. Man in his savage state found that he had to work for his living, and also to fight for it, with other men and animals. When men multiplied upon the face of the earth, they found it necessary to form communities and nations for mutual help, protection, or aggression. They had to defend their land and houses against other men who wanted them, or they had to extend their boundaries as their population increased.

The so-called "curse of labour" lies on all those communities and nations, and on every individual composing them, and always will. No man or nation can live without work, and without competing, struggling, fighting for it. When man had formed communities or nations he had realised that there were three *essential* things which he had to do. He had to work, and breed, and fight. If he did not work he starved and died. If he did not breed he ceased to be a community or nation, was unable to keep up the numbers necessary for protection, and was driven out of the land he occupied, or was absorbed into a more virile community as a slave. If he did not fight he was wiped out, his women appropriated, and his children killed or kept alive at the discretion of his more successful competitors for existence.

Every member of these communities or nations was and is, struggling to better himself, and has the right to do so, but only so far as his actions and methods are not detrimental or hostile to the common good of the whole. In the same way, any section or class of the community which has a common interest or profit to obtain, may prosecute that object only so far as may be without injury or prejudice to the prosperity and safety of the whole. The protection of the members composing it, and the promotion of their common good, are the cause and object of the formation of communities, and the conservation of this common good, which is the prosperity of the whole, is essential to the existence of every nation. The disruption of a community or nation, and its ultimate extinction, are certain when any of the various classes, sections or conflicting interests in it is allowed to gain or profit unfairly or unjustly at the expense of the others. Disintegration is inevitable unless the interests or profit of every individual and class are not merely subordinate, but contributory to, the national security and welfare.

All training and education, therefore, should be designed to increase the prosperity of the community first and of the individual next, because the individual cannot exist as an isolated unit outside the community. It is a simple matter to educate the unit so far as he has brain capacity, if sufficient skill, time and money are spent upon him. It is a very different thing, and not a simple matter so to educate him that a direct and visible benefit to the community and country, as well as to himself is the result. The proof of the fitness of democracy for self-government is the recognition and admission of the fact that no man, no class, no section of a community "liveth to himself alone," or can prosper at the expense and to the injury of any other individual class or section. All must help and contribute to the safety and prosperity of the whole.

It is necessary to enumerate these elements of national prosperity because at present the declared policy of various sections of the community is to live at the expense, and if necessary by the destruction of the others, which means national suicide, and unfortunately recent legislation has, unintentionally no doubt, supported this policy of national self-destruction. Consider the effect of these immutable economic principles on this country, which at the end of the present war will be burdened by a gross debt of not less than 7,000,000,000*l*. Mr. Fisher sincerely believes, and so do many others, that his Education Bill will produce more efficient workmen, who will thereby be able to reduce this debt more easily and quickly, whilst maintaining themselves in greater comfort than heretofore, but in endeavouring to make the coming generation fitter to bear the burden, they are likely to increase it by putting it on fewer shoulders.

Education, like any other tax, may easily be made such a burden on the community that there will be fewer children to educate, unless they are imported, because potential parents cannot afford to rear indigenous stock. It is men and women, not land, buildings or machinery who produce things, therefore the more producers the lighter is the burden on each individual unit. For this reason no country can be prosperous or retain "its place in the sun" unless its population is an increasing one.

Because all life, individual and national, is a struggle for existence and for betterment, every man has not merely to work, but to work profitably. The individual and community live not by what they can make, but by what they can *sell* in the international market in competition with similar articles made by other labour in other countries. Those live best who can sell most and sell cheapest, therefore education and training must be directed to making the community, individually and collectively, skilled and efficient in their respective occupations, for it is by proficiency in one particular trade or business that men make their living and become prosperous.

Because it is men and women who produce things, earn money and pay taxes, the community prospers by growing, by increase of population, which is increase of producers, therefore education must not be a burden on parents or put any handicap on the production of children. Because there will always be communities and nations poorer, more prolific, more virile, than others, and struggling for "a better place in the sun," every other community that wishes to live in peace and to prosper must be trained, prepared and ready to defend themselves against oppression or aggression, or assuredly they will go under. Every man need not be a soldier, a professional fighting man, but surely we realise now that every man should be trained to arms, skilled in the use of them, and ready to use them, when necessary. No League of Nations can be of any value as a peace preserver unless all its members are able and willing to compel obedience to its decrees. It is force, the sword behind the judgment seat, that makes the law respected and obeyed.

Mr. Fisher's Bill, instead of helping the individual and community in these three essential duties on which their very existence depends, is to handicap them. It will not make men fitter for their work because nearly all labour and trade are now specialised and must be learned early. It is not by a smattering of knowledge, by "general education," that men are fitted for their life-long struggle, but by special knowledge of one particular trade or industry, and skill in most industries must be acquired early.

Instead of helping to increase the population, or improve the race, Mr. Fisher's Bill will prove the most disastrous and effective check on the production of children that has yet been devised. He will not see (for he has been told often enough) that parents will not rear children who are to be a burden on them. Other parents in other countries get help from their children at a much earlier age than is permitted here, they live more economically and have simpler tastes, they are cheaper producers of all products, and the people here have to compete with them in the international market for a living.

It will not teach the nation or the individual how to defend themselves against attack or aggression, or how to help their weaker friends in such a case, for military training is expressly excluded. Yet surely it is seen to-day by every thinking man, that if we had been a nation of trained men prepared and ready to defend ourselves and our friends, this war would in all probability never have occurred, or if it had, would have been finished long ago at a fraction of the cost in blood, misery and money that has been incurred. Surely also no one dreams that all wars are to end with this one, or that they can be prevented in future by a League of Nations who rely on arguments and arbitration instead of aircraft and artillery.

It will do one thing, an evil thing—it will perpetuate the present sectarian, clerical, interference with popular education, and foster the prevalent religious jealousy and priestly intolerance, for it is to be denominational, whereas it should be secular. We have a hundred varieties of Christian religion, but only one country, and we never shall be a united community so long as local majorities are allowed to force their particular religious views on their neighbours' children. Popular education must be secular so far as the school teachers are concerned.

The people did not ask for this Bill. An overwhelming majority of those whom it will most affect, the fathers of the coming generation, are in the trenches, and have never heard of it, nor will they have an opportunity of voting against it as they assuredly would. For this reason it is not an honest Bill. It is being pushed through Parliament by members who have lost touch with their constituencies and who have no mandate to vote for it because it has never been submitted to the electors.

Yours faithfully,

PETER SWAN.

April 10, 1918.

CONCRETE SHIPS.

TO THE EDITOR OF ENGINEERING.

SIR,—One most important point seems to us to have been overlooked in the discussions on the employment of concrete for sea-going vessels, viz., the action of sea water on concrete. We take it that, as some well-known concrete firms have been mentioned as associating themselves with the design of concrete ships, that this point has not been overlooked.

The action of sea water on concrete has been very carefully studied in America, but it does not appear to have received so much attention in this country. In some places reinforced concrete appears to stand remarkably well when exposed to sea water, and in other places it has failed unexpectedly. We believe the reason is that the magnesia salts in sea water have a deleterious effect on concrete, if the sea water can once penetrate below the skin of the concrete, and that the essential point is to protect the skin from abrasion. This object is easily obtained in permanent structures by protecting the concrete with wood fenders, &c., and we believe that concrete so protected shows no sign of sea water action, while contiguous work, not protected from abrasions, has deteriorated rapidly. We believe it would be advisable to give a very thorough coat of tar, or other bituminous matter over the whole of the concrete surface exposed to sea water.

As regards the torsional strains which were mentioned as likely to occur in sea-going vessels, ought not this to be provided against by steel arranged spirally in addition to other bent-up steel?

Yours faithfully,

TRENT CONCRETE, LIMITED

(E. F. S., Chief Engineer).

Trent Concrete, Limited, Trent Navigation Buildings, Wilford-street, Nottingham, April 12, 1918.

LONG-RANGE GUNS: ERRATUM.—In the letter on the subject on page 408 of our last issue the total weight of filled shell should have been denoted by W, and not by *w*, as printed.

ADVISORY COMMITTEE TO THE DEPARTMENT OF OVERSEAS TRADE (DEVELOPMENT AND INTELLIGENCE).—The following gentlemen have been appointed to serve as a committee to advise the Department of Overseas Trade (Development and Intelligence) on matters relating to the activities of the department: Sir Francis Barker, representing the Federation of British Industries; Sir Algernon F. Firth, Bart., representing the Association of Chambers of Commerce of the United Kingdom; Mr. W. H. N. Goschen; Mr. W. L. Hichens; The Right Hon. Lord Inchcape, G.C.M.G.; Mr. Walter Leaf; Mr. Kenneth Lee; Mr. G. A. Moore; Mr. J. W. Murray; Sir George A. Riddell, Bart.; Mr. C. V. Sale; Captain Albert Smith, M.P.; Colonel Frank H. Wedgwood.

TRAINING OF MOTOR VOLUNTEERS.—A general meeting of the officers, N.C.Os. and men of Group No. 1 of the City of London Motor Volunteer Corps was held recently, under the chairmanship of Major E. S. Shrapnell-Smith, Officer Commanding, who reported that over 300 commercial motor vehicles had been enrolled in the group, which was one of the first to be officially recognised by the War Office, and one of the strongest and oldest in the country, having been formed in January, 1915. The new Army Council instructions now made it necessary in order to secure greater efficiency, that the men should attend a certain number of elementary drills in infantry training, and in interesting lectures on march and convoy discipline and the work of the A.S.C. M.T. There was no subscription for drivers, as the whole of the expenses were met by the officers and a number of firms who were in sympathy with the movement. Notwithstanding the petrol difficulty, Group No. 1 had, during the past six months, carried out many important operations on the direct instructions of the War Office, and it had been a source of gratification to him to read the excellent references to their work in reports to the War Office by the commanding officers of the units concerned. There were still a number of vacancies, and full particulars could be obtained on application to the Adjutant, Captain F. G. Bristow, at the Headquarters 83, Pall Mall, S.W. 1.

THE CONTROL OF LARGE AMOUNTS OF POWER.*

By E. B. Wedmore, Member.

I. Introduction.

The increasing use of electrical energy and its economical production require the use of larger generating stations and the linking together of existing plants. These extensions involve something more than the use of larger units and the adding of unit to unit. New conditions are reached. Factors which were negligible in smaller aggregations of plant become serious and limiting features.

The forces accompanying a disturbance are increased and the total number of disturbances to which a system is subjected increases automatically with each extension; thus there are introduced new problems in the design of individual parts of the plant and in the arrangement of them.

There are no insurmountable difficulties in the design of larger machines, heavier cables, and of switchgear all able to cope with larger forces than have yet been met with, but a little consideration will show that the limiting features are to be looked for not only in the generating station but in the distributing system. Stations and networks spread over a large area may be coupled together without necessarily seriously modifying the forces to be dealt with at any point, but a striking characteristic of developments now in prospect in the principal industrial areas is the increased concentration of large amounts of power in small areas. This inevitably follows the extended use of electricity for domestic purposes as well as for power production, and introduces new conditions not yet fully recognised.

One may double the size of a generating station with advantages in economy and without excessive expenditure on switchgear to take care of the conditions in the station itself; but for every machine, switch, and conductor in the main station there are large numbers of smaller machines, switches and conductors in the distribution system, and if these also are subjected to increased forces a very heavy expenditure may be necessary to ensure satisfactory service. Not only is this true as applied to an individual town, but similar conditions may arise where a large bulk supply scheme is devised and a number of existing small plants are linked up to a common and larger source.

It is therefore very necessary to give full consideration to the new conditions introduced, and in this paper an attempt is made to anticipate the probable developments of the immediate future, and to show how the conditions arising may be dealt with.

The problem of maintaining continuity of supply and of protecting the plant is found to require for its solution the proper proportioning of the impedance of the different parts of the system.

There are also a number of practical details to be considered in the design and arrangement of the distribution apparatus and of the feeder system. The employment of current-limiting reactances has been already dealt with in a paper by Messrs. Faye-Hansen and Peck,† but the subject has been treated afresh with the object of ascertaining the limiting features in the practical applications of reactance and presenting them in a form for immediate use.

II. Prospective Developments.

It is not by examination of designers' data that we can predict future developments because in so far as details of existing practice are good we can find reason why they should not be changed. We have, rather, to examine changes in conditions. Not the least of these in this case is a general improvement in statecraft which justifies us in anticipating a more rapid development of electrical business.

Engineers have long ago anticipated the possibilities of big developments in the use of electric power, and in its more economical production and distribution. The use of electricity in metallurgical and chemical processes is opening up a new field, but apart from new outlets there is scope all over the country for manifold extensions in the use of electricity for domestic and general industrial purposes.

The whole subject has been brought into public notice through the forcible representations of the Coal Conservation Sub-Committee of the Reconstruction Committee in their recent report on Electric Power Supply in Great Britain (Cd. 8880, dated December 7, 1917).

In this report the design and use of alternating-current generators in units up to 50,000 h.p. and over has been discussed. In this country machines are already building in sizes up to 40,000 k.v.a., and larger sizes are building in the United States. Stations have been laid down for an ultimate output exceeding 200,000 k.v.a., and this figure has been approached in installations already in operation.

It is thought that in this country for some years to come the requirements will be met with stations not greatly exceeding 100,000 k.v.a., and mostly with generating units not exceeding 20,000 k.v.a. to 30,000 k.v.a. maximum rating.

It is not only the difficulties of water supply that tend to limit the size of stations, but in areas within which 200,000 k.v.a. can be utilised there will generally be economy in distribution by the employment of two 100,000-k.v.a. stations, it being under suitable conditions more economical to transport coal and water than to transmit electricity.

In neighbourhoods requiring several large interconnected stations, units above 30,000 k.v.a. can be employed economically. In some districts there may be several such stations widely separated but interconnected, whilst in others, where the demand is less or where the facilities for cheap power production are concentrated in small areas, one or more large stations situated near together may supply a wide area of high-voltage distribution. Waste-heat plants and other local economical sources of power will be utilised by connecting these to the distribution system.

In this paper the station with 100,000-k.v.a. output is taken as typical, but consideration is also given to the linking together of such stations, and of smaller sources of power such as waste-heat stations and existing generating stations of limited capacity. As for the size of generating units, it will be seen in what follows that the general use of generator units of the order of 50,000-k.v.a. output would throw excessive stresses on distribution apparatus and small plant generally unless special precautions were taken. There are, however, other considerations also which point to the use of smaller units.

In the first place the question of spare plant has to be considered. We have to consider that a large unit may fail at a time when another similar unit is temporarily out of commission, pointing to the provision of two spares of the largest size.* This is increasingly important on large systems where more and more services become dependent upon the electric supply, and where the load factor is high. The time required to restore to service units of this magnitude that may have been put out of commission is much greater than in the case of units with which most of us are familiar.

This and the fact that such large units could not be employed economically except on large interconnected systems with a total output greatly exceeding 100,000 k.v.a., all support the contention for the general use of machines of 20,000 k.v.a. to 30,000 k.v.a.

These machines, generating at about 6,000 volts, will be used mostly with transformers stepping up to 20,000 volts or 30,000 volts for transmission. Generally the machine and transformer bank will form one unit, all switching being carried out on the high-voltage side. There is likely to be an increasing use of overhead lines for distribution of small amounts of power over large areas, but large amounts of power will be distributed through underground cables, on account both of increased freedom from disturbance and of convenience in negotiating densely populated areas.

III. Limitation of Disturbances.

Means must be found to ensure maintenance of voltage at all parts of the system and to prevent the disturbance of running machinery.

Means must also be found to limit the power which can be concentrated at any point on a fault occurring, and to a figure not calling for excessive expenditure in the construction of individual pieces of apparatus.

That special steps are necessary will be abundantly clear when it is stated that if practice hitherto prevailing is followed in the extension of existing plants, switchgear on consumers' premises may be subjected to forces comparable with those now met with in large generating stations. The rupturing capacity of oil switches is dealt with in Appendix I, page 442.

By suitably proportioning the impedance of the different parts of the system, and by the employment of quick-acting selective protective apparatus, we can, however, both limit and localise these disturbances.

IV. Limitation by Sectionalising and the Employment of Reactance.

By the crude method of sectionalising the plant we reduce the conditions to what they would be on small plants, and this has been done extensively. The object, however, of large combinations of generating plant is economy in production, and this is obtained by an interchange of energy between the different sections, which enables larger and more economical units to be employed, reduces the number of spare machines necessary, and improves the load factor. Thus it is interchange of power we have to provide for.

On a large plant we can to a considerable extent regain the easier conditions of small plants by dividing the system into sections and paralleling these through reactances. This will admit of the interchange of energy for purposes of economy, and at the same time limit both the interchange of energy during severe faults and the disturbance of sound sections.

The employment of reactances for interconnecting, whether between bus-bar sections in an individual station, in trunk mains between bus-bars in different stations, or in interconnectors between adjacent parts of the distributing system, has the distinctive merit that, so placed, they carry only that portion of the load being transferred from section to section, and thus waste a minimum of energy and do not interfere with regulation.

Reactance may also be employed in series in any part of the system, but, so used, the reactance will have to carry the total load fed to that part.

Wherever employed the reactance limits the disturbance in all parts of the system beyond it and tends to isolate the disturbance from all parts nearer to the source of supply.

The desired results will be most economically obtained when interconnecting reactances are employed, but if the inherent reactance of the circuits, transformers, &c., is insufficient adequately to localise the disturbance, the employment of a certain amount of artificial reactance in series will be necessary also.

The different methods of employing reactance with their advantages and disadvantages are set forth in the Schedule given above.

The conclusions in the schedule are now to be explained and illustrated.

In discussing the use of reactance it is found convenient to rate the reactance in terms of the percentage reactive voltage-drop it will give on the full-load rating of the part of the plant with which it is associated. Just as we speak, for example, of a transformer having a reactance of 4 per cent., so we speak of a bus-bar section reactance of 10 per cent. based on the current rating of the section. This rating of reactances is considered further in Appendix II.

In this paper the rated current is assumed throughout to be "maximum rating," as recommended by the British Engineering Standards Committee.

The design of current-limiting reactances is dealt with in Appendix VII.

V. Limitation by Generator Reactance.

Reactance may be employed at the source, viz., in or with the generators themselves, where it need not interfere with the losses. It is anticipated that this method will be carried further than it has been hitherto. Most generating sets will be used in conjunction with step-up transformers, the machine and transformer forming one unit. In this case the transformer reactance will be additional to that in the machine and

SCHEDULE.

Control of Large Amounts of Power by Use of Reactance.

Requirements.
To limit the area affected by a disturbance at any point.
To limit the power concentrated at any point on a fault occurring.

Characteristic.
Wherever employed, reactance limits disturbance in all parts of the system beyond it, and tends to isolate disturbance from all parts nearer to the source of supply.

Means.

A. *Utilisation of Inherent Reactance.*—Advantages: Saves cost of special reactances and does not add to resistance and consequent losses.
Limitations: Where the load is at all concentrated, cannot be carried far enough for economical reasons.

B. *Utilisation Artificial Reactance.*—Advantages: Can be located where most effective.
Limitations: Must not interfere with regulation.

Method of Employing Reactance in General.

I. *Reactance in Series.*—Advantages: Easy to apply.
Limitations: Carries total load fed to part protected.

II. *Reactance in Parallel.* (Sectionalising or interconnecting)—Advantages: Carries only portion of load transferred. Wastes less energy. Interferes less with voltage regulation.
Limitations: Requires sectionalising of distributing system. Is not sufficient alone if good regulation maintained.

Methods of Employing Reactance in Series.

(a) *In Generator.*—Advantages: Cheaper. Does not hinder voltage control under normal conditions.
Limitations: Considerations of design of machine. Must not swamp isolating effect of bus-bar and feeder reactances.

(b) *Added to Generator.*—Advantages: Limits current which can flow into faulty machine.
Limitations: Increased cost and space required. Must not swamp isolating effect of bus-bar and feeder reactances.

(c) *In Feeder.*—Advantages: Gives best protection to rest of system.
Limitations: Interferes most with voltage on part protected.

(d) *In Group of Feeders.*—Advantages: Minimum number of reactances required. Protects feeder switchgear.
Limitations: Involves several feeders where fault in one.

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* Paper read before the Institution of Electrical Engineers.

† K. M. Faye-Hansen and J. S. Peck, "Current-limiting Reactances on Large Power Systems," Journal I.E.E., 1914, vol. lcii, page 511.

* This limit of two spares of the largest size is not quite accurate, however, as if we provide an equivalent in smaller machines the cost is reduced. Thus with a 50,000-k.v.a. unit and three spares of 25,000 k.v.a., any two machines can be shut down and leave not less than 50,000 k.v.a. available. The larger set will be available most of the time, so that the slight loss of economy during the short period when it is replaced by two smaller machines is negligible.

will add, say, 4 per cent., but there is no reason why the transformer should not be designed to give more than this, and at a lower cost than that of employing a separate external reactance.

There is a practical limit to the extent to which satisfaction can be obtained by the use of generator reactance, and that arises from the fact that reactance in this position serves only to reduce the magnitude of the short-circuit currents and does nothing towards maintaining the supply voltage in the rest of the system in the event of loss of voltage by a fault at a point. In order to maintain the supply voltage, we must employ a proper ratio of bus-bar reactance to generator reactance and of feeder reactance to generator reactance; and as it will be found that the amount of bus-bar or feeder reactance which can be used is limited on account of interference with regulation, it follows that the generator reactance is also limited if a proper ratio is to be maintained between the two.

We are concerned with the magnitude of the rush of current which follows the development of a fault. The heavy current demagnetises the field and reduces the current values, as indicated in Fig. 1, but at the first instant the field is sustained by eddy currents set up in the magnetic circuit, and the current is limited solely by the reactance of the windings.

VI. Limitation by Feeder Reactance.

The employment of artificial reactance in series with the load leads in any case to waste of energy and impaired regulation, and is therefore to be sanctioned only where no better solution is available.

Resistance and reactance in an individual feeder anywhere in the system affect disturbances in the following manner:—

1. The feeder impedance helps to maintain the voltage on all parts of the system connected on the source side of the impedance.

(2) The feeder impedance assists in limiting the magnitude of the fault current at any point beyond the impedance.

(3) The voltage at all points beyond the impedance is equally disturbed.

If artificial reactance is to be employed, functions (1) and (3) call for the reactance to be located as near as possible to the point to be protected, whilst function (2) calls for the reactance to be located as near as possible to the source of supply.

Inherent reactance may be utilised, however, in such a way as to serve all three functions, as may be seen by comparing Figs. 2 and 3. Fig. 2 shows power fed through eight feeders to two substations and distributed through 10 outgoing feeders. In Fig. 3 the same eight feeders are divided into four groups of two and there are 16 outgoing cables of smaller section.

It is clear that in the latter diagram we have not only increased the number of sections and thereby reduced the area affected by a given fault, but we have doubled the impedance between each substation and the main station, and greatly increased also the impedance in the outgoing feeders. Thus by separation of feeders we can introduce more impedance both near the source and near the parts to be protected. At the same time if the total section of copper remains the same (neglecting the slight impairment of load factor) the losses are not increased and the regulation is unaffected.

In large systems where step-up and step-down transformers are employed, these introduce further inherent reactance, so that in practice, except where there is considerable concentration of load, the use of artificial feeder reactance should be avoidable. Where artificial reactance is required, it should be put as near as possible to the point to be protected. Thus in Fig. 4 reactance should be inserted at X only if it is necessary to protect the substation plant. For the protection of consumers' apparatus position Y is the best, as this gives better voltage regulation.

The use of series reactance interferes with the regulation to an extent which may be quite serious for lighting unless the energy is transformed to continuous current. The permissible pressure drop ultimately decides the practicability of the proposition.

If the power factor of the load is 80 per cent., then the magnetising component is 60 per cent. and a 10 per cent. reactance will cause a 6 per cent. drop, and for other sizes *pro rata*. In a case where the inherent reactance limits the kilovolt-amperes on short-circuit to 100,000 k.v.a. to 150,000 k.v.a., for example, this figure can be reduced to 20,000 k.v.a., or well within reasonable limits for consumers' premises, by the employment of series feeder reactance introducing potential drops as follows on a load circuit of 80 per cent. power factor:—

Load. K.v.a.	Potential Drop. Per Cent.
1,000	2½
2,000	5
5,000	12½

In this case the potential drop could be reduced only by improving the power factor, or by the use of less reactance and switches of larger rupturing capacity.

We shall see, however, that much better conditions can be obtained by a proper use of reactance at the generating station, in the machines, bus-bars, or feeders as required, to reduce the short-circuit currents at the substations.

In new large power stations it is wise to provide space for the possible addition of feeder reactance.

We conclude that inherent reactance should be utilised as far as possible, and additional artificial reactance should be used only to ensure that disturbances should be sufficiently localised and plant adequately protected against excessive stresses.

These two conditions require a similar distribution of reactance in the system, but the results obtainable from the standpoint of voltage disturbance depend upon the kind of plant employed.

Limitation of Voltage Disturbance.—We may consider three typical cases, viz.:—

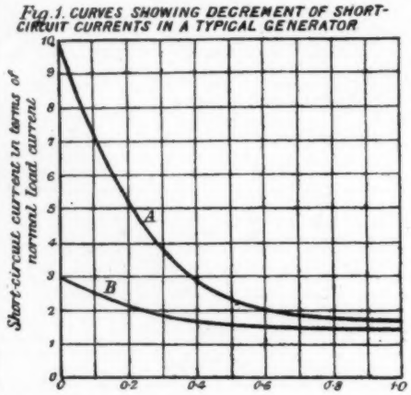
(*a*) Distribution for lighting through transformers.
(*b*) Distribution through induction motor-driven sets.
(*c*) Distribution through rotary converters and synchronous motors.

(*a*) Where the distribution is by transformer the voltage must necessarily be disturbed to an extent visibly affecting the lighting on sections adjacent to the faulty one, but the disturbance will last only until the protective gear has isolated the fault.

(*b*) In the case of induction motors a heavy fall of voltage is not serious so long as the fault is cleared in about 2 seconds or less, which lies well within the capacity of modern protective apparatus.

(*c*) In the case of rotary converters and synchronous motors, we have only approximate data, but can form a good general idea of what is required. A rotary converter running fully loaded will not be pulled up if the voltage falls to one-third or one-quarter of normal, but the machine is sensitive to sudden changes of phase angle. The reactance which limits the voltage drop also reduces the phase-swinging. Faults remote from the source present no difficulty, but we cannot employ sufficient reactance in outgoing feeders in the generating station to prevent the voltage being pulled down on a fault. It is likely, however, that the machines on sound circuits will not be disturbed if the voltage does not drop below 50 per cent. of normal at the source. At the first instant the drop will be much less than this, but the generators will be quickly demagnetised and the voltage will approach the limit in less than a second.

Fig. 1. CURVES SHOWING DECREMENT OF SHORT-CIRCUIT CURRENTS IN A TYPICAL GENERATOR



A. Dead short-circuit
B. Short-circuit limited by reactance in circuit

If the generators have a short-circuit reactance of 15 per cent. and are furnished with potential regulators, it is likely that they would require a feeder reactance of 33 per cent. based on the generator rating to meet this condition. If now there are 10 feeders (and about the same proportion of spare feeders and spare machines), this requires at full load a feeder reactance of only 3·3 per cent. based on the feeder rating. At times of light load, however, when, say, there is only one machine running, the feeder reactance would have to be proportionately higher, so that it is clearly not possible fully to protect the rotary converters all the time, even with reactances in each outgoing feeder.

It should be borne in mind, however, that in modern practice where the mid-point of the system is earthed, all faults to earth will be cleared without serious voltage disturbance, and the large majority of cable faults in particular are of this character. Moreover, the above figures apply only to the worst possible case, viz., that of faults close to the source.

There is no doubt that the conditions are further greatly improved by the employment of quick-acting switchgear able to clear a fault in one-fifth of a second or less.

Use of Feeder Group Reactances.—A group of feeders running between two common points may be treated as a group and have a common reactance. The number of reactances may be reduced in this way and further protection given to the switchgear controlling individual feeders. The reduction in cost of reactances is partly offset by the additional cost of the necessary group bus-bar and group switchgear.

Where feeders are grouped only at the source it is better to employ separate feeder reactances rather than group reactances, so that disturbances on any one of the sections fed shall be isolated from the others. In such a case, however, some group reactance may be employed on occasion to protect the feeder switches, as, for example, in incorporating existing feeder switchgear in a larger scheme.

VII. Limitation by Bus-bar Reactances.

The method of employing bus-bar reactances is intimately connected with the subject of the design and arrangement of the bus-bars themselves. This is dealt with in Appendix III. It is sufficient here to recognise that there are two distinct methods of connecting up the reactances, known respectively as the "star" and "ring" methods and illustrated in Figs. 10 and 11, respectively, page 443. It is shown in the appendix that the star design is generally preferable after considering the operating conditions. Either system will give about equal protection, but here again the advantage in the extreme case lies with the star design.

Sectionalising the Distribution System.—It is the system which has to be sectionalised and not the main bus-bars alone. Clearly the sectionalising of the bus-bars is of very little value if the sections are tied solidly together outside the generating station. This requires that there shall be a correspondence between the bus-bar sections and the sections of the distributing system. The ultimate plan must as far as possible be pre-arranged from the commencement so that adequate provision may be made in each section of the bus-bar for the ultimate equipment required by the corresponding section of the distributing system.

Current-limiting Effect.—In considering what results can be obtained by the use of bus-bar reactance the subject of the transfer capacity required is important, because for a given voltage difference between sections the amount of current to be transferred limits the amount of reactance which can be employed and therefore the amount of protection obtainable by this method. The subject is dealt with at length in Appendix IV.

In investigating the limiting effects of different combinations of reactances, the reactance associated with an individual machine, whether internal or external, or in the step-up transformer, is treated as one item, described as generator reactance and indicated by the letter A. The bus-bar reactances, however, connected, are indicated by the letter B. Thus in Fig. 5 A = 14 per cent., B = 14 per cent., and B/A = 1.

Fig. 2. ARRANGEMENT OF FEEDERS GIVING LOW INHERENT IMPEDANCE

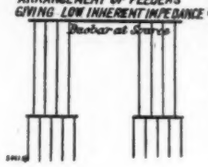


Fig. 3 ARRANGEMENT OF FEEDERS GIVING HIGH INHERENT IMPEDANCE

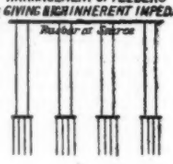


Fig 4 LOCATION OF FEEDER REACTANCES

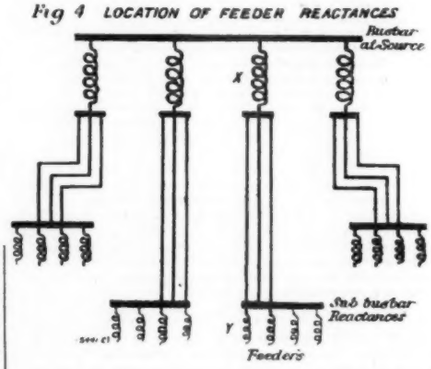


Fig. 6 gives a good idea of the results obtainable by the introduction of bus-bar reactances. The short-circuit current, on the assumption that no reactance is employed, is taken as unity, and the curves show how much this figure is reduced by the employment of bus-bar reactance. It will be seen for example that with B/A = ½ and with five bus-bar sections the short-circuit currents are more than halved. The results obtainable are investigated in detail in Appendix IV. From the data there given it will be seen, for example, that with five bus-bar sections, with generator reactance of 17 per cent. and bus-bar reactance of 6 per cent., it is possible to keep the maximum value of the short-circuit k.v.a. down to three times the plant capacity, instead of 10 times the plant capacity, a common figure at the present day. That is, we build a 100,000-k.v.a. plant in which the conditions will be no more severe than in a present-day 33,000-k.v.a. plant.

Provision of Spare Machines.—The arrangement of spare plant will be found to be a question which vitally affects the design and use of reactances. If we plan for five machines clearly we cannot employ six bus-bar sections, or a symmetrical arrangement of three, and if we use four the fifth machine cannot conveniently be connected up as a spare to any one section.

The number and size of machines should preferably be determined so that with adequate provision for spares the machine capacity will be divided equally between the sections, the number of sections being such as to give the required degree of protection whilst suiting the local conditions.

For reasons previously given it is assumed that there will generally be two machines in excess of the total corresponding to the maximum output; thus, of eight sections, two will be spare. There may be four bus-bar sections with two each, but the total maximum output

will be that of six, and the total maximum output of a section that of 1½ machines. This exercises a large influence on the reactance rating, as it limits the transfer of current necessary.

Transfer of Power.—We desire to transfer power from section to section for purposes of economy, and this transfer may amount to 20 per cent. to 70 per cent. of the capacity of a section. This transfer may take place in either direction. For it to take place at all it is necessary to set up a difference of potential between sections, whereas working conditions require that the sections shall be at substantially the same voltage.

The transfer of the energy component of current through the reactance will not require a potential difference greater than is necessary to overcome the ohmic resistance, and this will be some small fraction of 1 per cent., perhaps one-fifth with 10 per cent. reactance between sections. To transfer magnetising current, however, will require a relatively large potential difference, and this will be in fact the reactance drop at the current in question, and this proves to be the limiting feature. The obvious solution appears to be to transfer the load at a higher power factor and to make up the shortage of magnetising current by supplying it from the machine or machines tied to the section in question.

In pushing the use of reactances up to the limit it is necessary to utilise this method of maintaining the voltage, but it is not one which should be used under daily working conditions. It involves underloading one or more of the machines, extra care in running adjustments, and in case a fault occurs on the section receiving current, the voltage drop will be greater.

Fig 5 ILLUSTRATION OF RATING OF REACTANCES

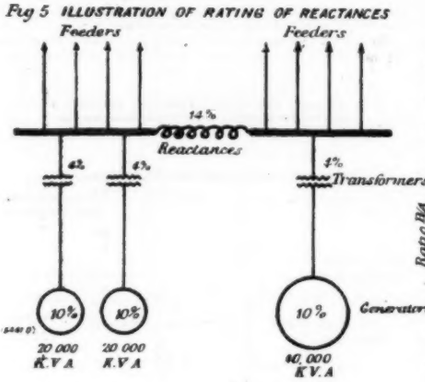
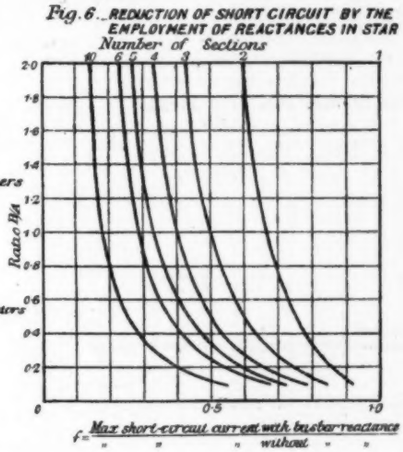


Fig. 6. REDUCTION OF SHORT CIRCUIT BY THE EMPLOYMENT OF REACTANCES IN STAR



Results Obtainable.—The practical possibilities of this method of control are investigated in Appendix IV, and it will be found that ample protection can be obtained by the use of generator and bus-bar reactances under normal working conditions without resorting to transference at a power factor above that of the load; but this method can be advantageously resorted to under emergency conditions.

As the result of this investigation it is possible to furnish a table showing results obtainable under practical working conditions, and this has been done in the appendix.

There is a preponderance of advantage in the use of two unit machines per section, or of course the equivalent in smaller machines. If larger units are installed later than were originally contemplated, these may be of twice the size and arranged one per section with suitable reactances and without materially affecting the short-circuit factor.

As a typical example of what can be done we may take the case of five sections and two machines per section. Here with generator reactance of 15 per cent. and bus-bar reactance of 7½ per cent. we get a short-circuit factor of 3·3 on the maximum output. That is, a station rated to give 100,000-k.v.a. output would give 333,000 k.v.a. on a fault between phases near the source.

Protection of Live Load on Sound Sections.—In considering the use of feeder reactances it has been shown that where a phase-to-phase fault occurs on the load side of the reactance, it is possible to maintain sufficient voltage on the source side of the reactance to keep rotary converters in step (see page 440, section (*c*)). In the example there given we have shown that the reactance should have a value of about 33 per cent. based on the generator rating. Applying this to section reactances, the basis becomes that of a bus-bar section and the 33 per cent. applies to the total reactance between sections.

From what has been said above, it is evident that the use of any such reactances would seriously limit the energy transfer that could be made with any reasonable voltage difference between sections, so it is not possible by this means alone completely to protect running plant attached to sound sections. At the same time it is clear that the use of bus-bar reactances operates in a helpful direction.

The figures given apply to the sustained short-circuit values. At the first instant, and before the generator voltage is seriously reduced by armature reaction, the bus-bar reactances have a much greater effect on the voltage on the sound sections.

VIII. Improvement of Power Factor.

A study of the data now given will bring out the disadvantages associated with the low power factor prevalent in distribution schemes in this country, and it will appear that the requirements for maintaining supply, as well as the conditions for diminishing losses, will be improved if a higher average power factor, such as 90 per cent., is obtained. In these respects present-day American practice has the advantage.

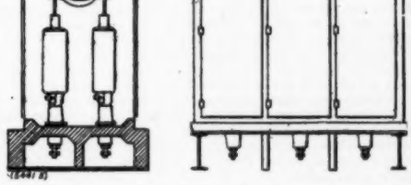
IX. The Interconnection of Stations.

Where relatively small and remote sources of power are coupled to a large system they improve the supply in their immediate neighbourhood. It will generally be found that the inherent reactance in the feeders and transformers is sufficient to prevent excessive increase of short-circuit currents in the neighbourhood.

Where the source is near a large station, it may be treated like a generator tied direct to an extension of the bus-bars, but will probably have more reactance than a single machine of equal output.

Where large stations are tied together this connection is similar to that between adjacent sections of bus-bars in an individual station, but differs in that a relatively smaller energy transfer is required, so that higher reactance may be employed. The energy transfer is made only for purposes of economy, and the individual station is already a self-contained economical unit. The short-circuit currents from individual sections in either station will not be materially affected if there are already three or four sections or more. If the stations are not tied directly but only through the distribution system, intermediate points will be subject to the short-circuit outputs of both stations.

Fig. 7. OIL SWITCH SHOWING GOOD INSULATION TO EARTH AND BETWEEN PHASES



Limitations Affecting Parallel Running.—The question now arises how will the employment of reactances between sections affect parallel running. This becomes particularly important in the case of stations remote from one another tied together for economy. Such ties may not be of large cross-section and may therefore introduce considerable resistance.

The theoretical treatment of this and similar cases has not been entirely satisfactory, but we may recognise that there are lower and upper limits to the reactance between which we can get satisfactory operation. It has been found that it is not generally practicable to obtain stable running conditions where the ohmic value of the total reactance in circuit between the machines is less than about twice the resistance. This necessitates the employment of external reactance in series with long underground tie cables of small cross-section. Where, however, there are step-up and step-down transformers in the circuit there will be ample reactance.

There must be an upper limit also, and this also is not easy to determine. It is evident that if two systems are running steadily at about the same frequency and voltage, a very small transfer of energy and magnetising current passing through a high reactance will bring the two systems into synchronism. If now one system is seriously disturbed it will get out of phase with the other, but the small currents transferred will be insufficient to disturb the sound system and will eventually bring the system into synchronism after conditions have become normal and steady. Here we have parallel running without trouble but without utility.

If now we reduce the reactance in the tie we get heavier synchronising currents and some disturbance of the sound system, but the two systems take time to settle down after a fault is cleared on one of them, and during this time there is much phase-swinging. This oscillation tends to throw out synchronous machinery and is more serious than mere loss of voltage. The limiting values of reactance are somewhat indefinite, but experience indicates that they are well above the value contemplated in this paper. It is known that with the star design quite satisfactory results can be got with bus-bar reactances of 40 per cent. and more based on the section output, and upwards of 100 per cent. has been employed in a tie line between two stations.

X. Influence of Live Load on the Short-circuit Current.

In estimating the effect of reactance on the short-circuit currents no account has been taken hitherto of the influence of running machinery able to feed current back into a fault. This factor is generally a relatively small one. It complicates the issue but must not be lost sight of. In determining the short-circuit current that may flow at any point it is necessary to add the current, due to such machinery, which will flow through the impedance of any feeders, transformers, &c., located between the machines and the point in question.

The short-circuit current, for example, near a large substation with rotary converters may be considerably increased by the current the converters can pump back.

XI. Limiting Effect of Fault Resistance.

One must not expect to find any protection from internal resistance of faults, except when the fault is to earth through a poor earth connection or includes a long open arc.

Where porcelain insulators are mounted in brick or stone the supporting wall reinforces the insulation, and, even if a cracked insulator discharges, the current at 6,000 volts will be quickly reduced from perhaps 5 amperes to a negligible figure as the wall dries by the heat generated.

In the case of carbonisable material, however, as in cables and machine windings, the energy liberated at the fault will cause the conductivity to develop in a small fraction of a second to a figure offering no further limiting effect.

The development of a fault is sometimes stopped at an intermediate stage by quick-acting switchgear set to operate at a few amperes, but this is not a means which can be relied on for effectively limiting the stresses at a given point in the system.

Limiting Stresses by Preventing Faults between Phases.—As faults to earth can be positively limited by the employment of resistance in the earth connection, it is only faults between phases that present a serious problem. The likelihood of such faults occurring can be greatly minimised by appropriate design.

When conductors are air-insulated they may be separated by substantial insulating barriers and kept clear of earthed metalwork. The barriers should be sufficiently large and substantial to confine the disturbance arising on failure of the apparatus they separate.

A good example is to be found in a large oil switch constructed as in Fig. 7 with insulated tanks, those on each pole being enclosed in a stone or brick cell.

Conductors surrounded with insulating material may be further separated by earthed metal barriers so arranged that a fault to earth is confined to the phase on which it occurs. A good example is found in a machine in which the conductors throughout their length, including the end turns, are covered with insulating material and separated by earthed metal parts with which they are in intimate contact. A breakdown on such a machine must arise as a fault to earth, and is localised by the formation of a good enclosed conducting path to earth. The risk of open arcing is minimised, and consequently the risk of the fault spreading to other phases and consuming the whole machine.

XII. Limiting Disturbances by the Use of Protective Relays and the Like.

The advantages obtained by the use of selective protective apparatus on large distributing systems are now generally recognised. They play an important part in economical distribution and an essential part not only in localising disturbances but in limiting their duration. This latter function is useful in preventing the development of disturbance due to unstable conditions, as for example in parallel running, but is especially important on large plants where the factor of safety against overheating on short-circuits is likely to be small.

The use of such apparatus throws a severe duty

on the switchgear, as switches have to clear faults whilst the currents are in the neighbourhood of maximum value (see Fig. 1), and the onus of clearing each particular fault is thrown on the individual switch or switches nearest to it.

For these reasons it is necessary to employ with the selective protective apparatus a system of stand-by protective apparatus which comes into use in case of failure of switchgear or selective apparatus. This takes the form of a system of fixed time-limit relays with graded settings which will come into operation only after failure in the first line of defence. A plant so protected will be as well off even on failure of the selective apparatus or distribution switchgear as plants have been in the past which were protected solely by the apparatus now used as a stand-by.

It is clear, therefore, that the provision of an adequate stand-by system justifies working with a lower factor of safety on the smaller circuits, especially if the conditions are favourable and the plant well designed in the first place to minimise the occurrence of severe faults. Existing switchgear may be retained on extension of plant, by relying on the stand-by protection to save the plant, if the margin is not too small. For example, switchgear rated at 20,000 k.v.a. might be employed to clear faults of 30,000 k.v.a. to 40,000 k.v.a. with stand-by protection, as, if the conditions are favourable to the switch, even the larger faults may be cleared satisfactorily and the severest disturbances should be few and far between.

In concluding, I desire to acknowledge my indebtedness to Messrs. The British Thomson-Houston Company, Limited, for facilitating the preparation of this paper, and to Mr. A. R. Everest and other of my colleagues, for valuable assistance.

APPENDIX I.

RUPTURING CAPACITY OF OIL SWITCHES.

Switches for any particular system must be rated to give satisfactory operation (1) under the severest emergency conditions, and (2) under normal service conditions. This requires the following :—

(*a*) They must break with certainty the maximum possible short-circuit they may be subjected to.

(*b*) The damage to the switch should be such as not to interfere with the commercial operation of the plant.

The second condition is the one which requires watching. For the usual conditions of electrical distribution it is quite sufficient if the switch will break the maximum short-circuit current twice and after this be capable of carrying normal current.

For railway service and other heavy power service, where heavy short-circuits may be frequently met with, the switch will require to withstand the corresponding frequently-repeated shocks and destructive arcing and must be rated accordingly.

Switches are obtainable able to cope with the severest conditions likely to be met with in this country for some time to come, and with a long record of good service behind them, giving the only possible non-speculative guarantee of their reliability under all manner of working conditions.

Switches have been employed in this country for many years past, having great mechanical strength, chambers able to resist high explosive forces, high speed of break and suitable contact design. These and other features all serve to give high rupturing capacity.

The designer's data are still largely empirical, and, as always happens in such cases, there are many ideas in circulation in the nature of half-truths, such, for example, as that switches should be compared by comparing the length of break.

The above features in design are being incorporated in an increasing degree in switches of small size, with the intention of increasing the rupturing capacity without increase of dimensions and without much increase of cost. This is all to the good, especially in the reduction of the cost of main switchgear for small plants, but some warning is required against carrying this principle too far in designing switchgear for use on small circuits subject relatively frequently to severe short-circuits. Increasing the strength, while it increases the power of the switch to withstand heavy stresses, contributes nothing towards reducing burning. Now, on switches of the design at present in general use we get very little burning and consequent gas production so long as we keep well within the rupturing limit proper to the dimensions of the switch, and after this is exceeded gas production and burning rapidly increase. The present demand for switches of great mechanical strength is not justified in so far as it arises from unfortunate experiences with over-rated switches. On the other hand, the increase of mechanical strength is valuable where the normal service is easy but where one has to provide against an unlikely contingency.

There has been no radical departure in the design of oil switches in recent years, and, until we have some important discovery to help us, switches will remain pretty much as they are now. Cost figures are of little value in the present state of the market, but it may be said that rupturing capacity and cost of switchgear equipments vary roughly in simple proportion.

In interpreting the maker's rating of oil switches it is very necessary to take account of the class of service for which the switch has been designed. A switch may be suitably rated for 1,000 amperes and 6,000 volts, and yet may be quite unsuitable for use on a 500-volt circuit where it is called upon to make circuit on several hundred amperes several times a day. It may have been designed with the large rupturing capacity required for emergency service on the busbars of a large 6,000-volt station, yet may have quite insufficient provision for withstanding the wear and tear on a circuit of the kind described. It may open with certainty 40,000 k.v.a. on a short-circuit without damage to the main contacts, and yet fail to destruction on what might appear to be the easy condition of controlling a 500-volt motor.

Switches for industrial use in factories and the like, if well designed, have a rupturing capacity of 5,000 k.v.a. to 15,000 k.v.a. Switches for consumers' premises and substations will rupture about 10,000 k.v.a. to 35,000 k.v.a. according to size. Next there are lines of switches rated in the neighbourhood of 100,000 k.v.a. to 200,000 k.v.a., suitable for stations up to 30,000 k.v.a. and for large substations on much larger plants, and finally a few switches rated to deal with any conditions likely to arise under conditions now anticipated.

Switches of such ratings can be purchased at figures suitable for their position in the system, and it will be found that these same limits correspond to what is required in the different parts of the system to obtain good running conditions from every standpoint.

APPENDIX II.

RATING OF REACTANCES.

In discussing the use and characteristics of reactances it is most convenient to rate them in terms of the percentage reactive voltage drop they will give on the full-load rating of the part of the plant with which they are associated. Thus we speak of a transformer with 4 per cent. reactance. In the same sense a reactance for a generator and rated at 10 per cent. is understood to absorb 10 per cent. of the normal voltage when carrying the rated current of the machine.

In the case of bus-bar reactances each reactance is associated with a section of the bus-bar and should be rated on the total generator capacity attached to the section, as its current-limiting effect is independent of how that capacity may be subdivided.

For example, in Fig. 5 the generator and transformer reactances are rated 10 per cent. and 4 per cent. respectively on their individual outputs, and the bus-bar reactance is rated 14 per cent. on a bus-bar section rating of 40,000 k.v.a. It will be seen that the reactance drop is the same for a fault on either bus-bar section although the generator capacity on one side is made up of two machines.

A feeder reactance may be rated at 3 per cent. when associated with the feeder, but if its effect on short-circuit is considered in connection with a generating plant of 10 times the feeder rating, it at once becomes 30 per cent. When rated in this way it may be added to the reactance of the generators expressed in the same terms. If, for example, the generator reactance is 10 per cent., the total is 40 per cent. based on the generator rating, and limits the maximum short-circuit current to 2½ times the rated output of the generators. Thus this method of rating enables the employment of reactances to be discussed in general terms and without reference to the size and voltage of the plant.

The current-carrying capacity which may be given to a reactance has no effect on its current-limiting action, and is determined by consideration of the amount of power to be transferred through it.

The actual dimensions of a reactance will, of course, depend both on its ohmic value and on its current capacity, and the individual reactance is best rated in amperes, carrying capacity, and ohms reactance at a given frequency, with the addition of working voltage, the working voltage determining the insulation required.

Fig. 8. ARRANGEMENT OF SWITCHGEAR SHOWING DUPLICATE BUSBARS

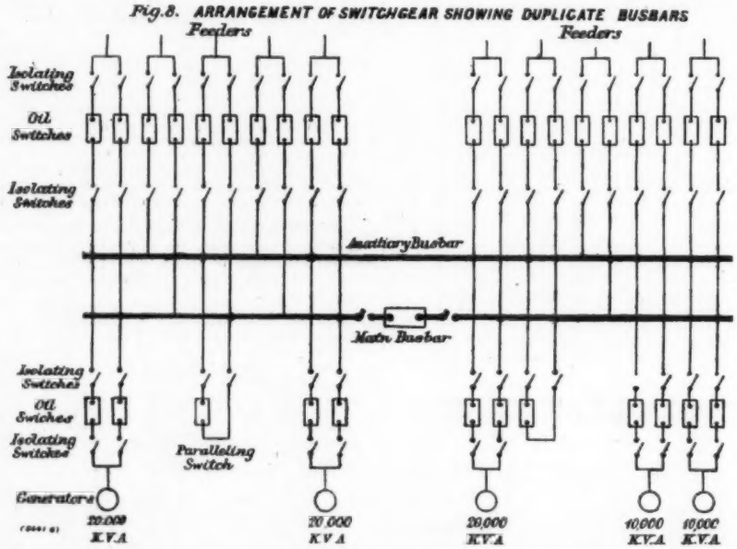
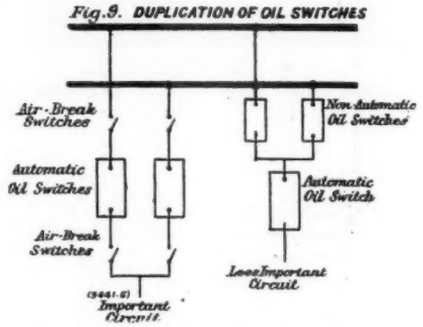


Fig. 9. DUPLICATION OF OIL SWITCHES



APPENDIX III.

ARRANGEMENT OF BUS-BARS.

In the provision of bus-bars and switches, something more is required than a simple straight bus-bar, or even a single ring bus-bar with one switch per circuit. Additions are made both to give duplication for safety and to provide flexibility. An extreme is reached by a design like an arc plug-board with provision for coupling any circuit or group of circuits independently to any machine. Such a design has been provided for (Proceedings of the American Institute of Electrical Engineers, 1916, vol. xxxv, page 886) and gives maximum flexibility with something more than duplication. In a station with five machines and 10 feeders, 15 bus-bars would be required, and 50 oil switches, as against one bus-bar with 15 oil switches.

The first essential is a spare bus-bar arranged so that any section can be shut down without interfering with supply. In the matter of switches it is recommended that all normal switching operations should be done by means of oil switches, and that air-break switches should be used only for isolating parts already made dead by oil switches. By this course adequate duplication is provided and the risk of serious trouble, due to operator's mistakes in routine work, is reduced to a minimum. Thus with provision for bus-bar paralleling and sectionalising, a station such as described may usefully employ, say, 33 oil switches without reactances (see Fig. 8).

Each addition to the primitive arrangement should be made to give a definite contribution to the results obtainable, and it is a general law of design that there will be increased economy if there is differentiation of function as well. For example, in the illustration given, one of the bus-bars is regarded as the main bus-bar and given a section switch. The other is regarded as the stand-by and would be used as a hospital bus-bar and for testing. The arrangement has all the advantages of a single ring bus-bar and at the same time provides a stand-by. It does not look like a ring because coupling switches are not shown at the ends, but each section is in fact coupled to both its neighbours, and the paralleling switches are located midway in the length to keep down the cross-section of copper. For the same reason the machine and feeder switches are alternated.

If oil switches are not duplicated, the fact of an oil switch being put out of commission for any reason prevents the corresponding machine or feeder being employed, and thus must lead in the long run to greater

expenditure on spare plant or a greater risk of serious lack of spares on emergency.

For this reason large machines should have at least two switches, but on less important circuits a compromise can be effected by employing one automatic oil switch and two inexpensive non-automatic oil-break selector and isolator switches as in Fig. 9, but economy is effected in first cost thereby only where the main oil switches are required to be of large rupturing capacity. It will be understood that the oil-break selector switches will break load current without danger, which an air-break switch would not do.

Arrangement of Bus-bars with Reactances.—Bus-bar reactances may be employed in either of two ways conveniently described as the star and the ring designs. In the star design the bus-bar reactances are paralleled by tying them to a common point or tie bus-bar as in Fig. 10, whilst in the ring design each bus-bar section is tied to the next through a reactance, as in Fig. 11.

Fig. 10. STAR DESIGN OF BUSBARS AND REACTANCES

Fig. 11. RING DESIGN OF BUSBARS AND REACTANCES

Fig. 12. ARRANGEMENT OF SWITCHGEAR FOR STAR DESIGN

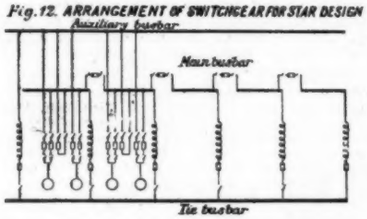


Fig. 13. ARRANGEMENT OF SWITCHGEAR FOR RING DESIGN

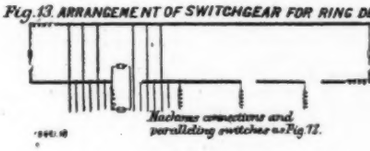
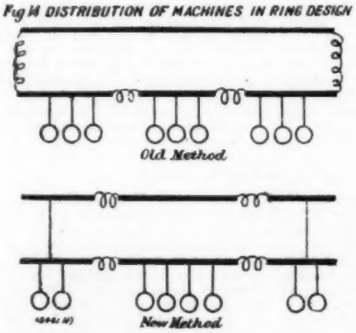


Fig. 14. DISTRIBUTION OF MACHINES IN RING DESIGN



In introducing reactances, two oil switches will be required with each. One is for paralleling through the reactance and the other for paralleling without the reactance. These switches are so employed that the number of machines tied direct to any group of solidly paralleled sections does not exceed the number proper to one section, and is not appreciably less. For example, with two machines per section, two sections should not be solidly paralleled unless at the time they have only one machine running on each. They will be separated by reactance immediately a third machine has been coupled to them. At times of heavy load all the reactances will be in use. At times of light load they will all be short-circuited. This is necessary, for it will be found that with reactances of the ohmic value required it is not always practicable to transfer light load through them without excessive drop of potential.

The complete switchgear in accordance with these recommendations is shown in Figs. 12 and 13, in which the feeders are omitted for simplicity.

It will be seen that, with the five sections shown, six reactances are required in each case. With the star arrangement the sixth is used to tie in the auxiliary bus-bar. With the ring arrangement a tie is required at both ends so as to ensure a reactance between this bus-bar and each adjacent bus-bar. Each arrangement is in effect a six-section bus-bar.

Each reactance as here shown is associated with a particular bus-bar to which it is solidly tied, but an isolating switch can be introduced at this point at small cost, giving greater flexibility.

The paralleling switches shown are all essential if duplicate main oil switches are not employed, but where the bus-bars can be paralleled through one or more pair of these duplicate switches, the paralleling switches are not essential. The two end ones should be retained for uniformity in the equipment for completing the ring main. Their use throughout as shown is recommended, however, as it simplifies and unifies the operations and the amount of thought required.

Advantages of the star arrangement with its extra bus-bar will be brought out by a study of these diagrams. Whatever sections are employed are paralleled by the simple operation of coupling them to the tie bus-bar, whereas in the ring arrangement it is not possible to maintain the ring formation when one section is shut down, or easy to follow the load-transfer conditions. Mistakes are more easily made which will leave the reactances cut out and too many machines operating in parallel on a section.

The third or tie bus-bar needs to be at least as well made as the other two, as a fault on that bus-bar involves all the sections and is fed through all the reactances in parallel. This bus-bar may be conveniently mounted close to the reactances. It is not duplicated, but may be ringed and broken up with air-break switches. It can be made dead at any time by a temporary sacrifice of economy in running.

There is no doubt, however, on the other hand, that in many situations it is easier to make a good design with two bus-bars than with three, so that there is a use for the ring arrangement. It will be shown that the load-transfer capacity of the reactances required in the ring arrangement may be as much as that required in the star arrangement, and the ohmic value is doubled for the same protective value, so the k.v.a. rating of reactances for the ring design may be twice that required for the star design and the cost consequently about 50 per cent. higher. This is partly or wholly offset by the omission of the third bus-bar. The ring arrangement, however, has the defect that under working conditions the ring cannot always be maintained closed. On shutting down any section of the bus-bar the ring is broken. If the design gives the correct limits with a closed ring it will now be found that there is too much reactance isolating the end sections of the open ring and consequent excessive pressure drop, whilst if the reactances are selected to compromise for this, clearly this can be done only at the expense of the protection afforded. The balance of advantage lies with the star design.

The defect in the ring system can be partly offset by making the end sections 30 to 50 per cent. smaller than the middle section and arranging them as shown in Fig. 14.

(To be continued.)

THE INFRA-RED SOLAR SPECTRUM.—Nearly thirty years have passed since Rowland photographed the solar spectrum from its limit in the ultra-violet at 3,000 Ångström units to 7,300 A. in the visible red. Many attempts have since been made to photograph the spectrum through the red into the infra-red, but the results obtained have not so far been comparable with those realised in the visible and ultra-violet spectrum. Although Captain Abney, working with a silver bromide emulsion, had extended the prismatic solar spectrum to 12,000 A. already in 1880, his apparatus did not admit of exact wave-length determinations, and in later attempts made by others, with the aid of improved sensitisers, the highest desirable accuracy was not secured either. The Bureau of Standards having recently found the dicyanin, as recommended by K. Burns, an excellent sensitiser for ordinary photographic plates, W. F. Meggers, of the Bureau, in April and May, 1917, photographed the solar spectrum in the infra-red up to 9,600 A. in Rowland's Laboratory, Johns Hopkins University, Baltimore. The resulting plates are reproduced in the *Astrophysical Journal* of January, 1918. The university buildings in the heart of Baltimore were not the most suitable place for such delicate work in Rowland's days, and the disturbances by street and railway traffic have become more troublesome since. Meggers could hence not prolong his exposures for more than 20 minutes, whilst certain iron lines about 11,000 A. required exposures for 6 hours or 8 hours; for lines about 7,600 A. an exposure of 1 minute was sufficient. He used a plane grating, 5 in. in length, with 20,000 lines to the inch, and lenses of 18 ft. focal length; his spectrograph gave a linear dispersion on the plate of 2 A. per millimetre in the first order spectrum. Iron lines, whose identity with conspicuous absorption lines in the solar spectrum had been established, were used as standards. Of the 350 lines so far measured in the range 6,800 to 9,600 A., 200 belong to iron, 63 to nickel, 27 to titanium, 22 to cobalt, 18 to chromium, 10 to silicon, 6 each to manganese and calcium, and fewer to other elements. The most striking feature is the total absence of any lines characteristic of the rare gases, though these gases are known, from laboratory studies, to have their strongest lines in the red and infra-red. But 1,600 lines of the plates remain so far unidentified, and the work is to be resumed with the Porter spectrograph at Allegheny Observatory, where conditions are more favourable, while the laboratory studies of infra-red spectra are continued in the Bureau of Standards.

AUSTRALIAN INDUSTRIES.

THERE is ample scope, says the Publicity Department, Commonwealth of Australia, Australia House, Strand, W.C. 2, for engineers and iron and steel founders in Australia. Large works have already been established there and substantial profits made, but the output supplies only a fraction of the demands. According to the "Commonwealth Year Book," the value of the total output of engineering, ironworks and foundries in Australia in 1913 was 8,315,000*l.*, while iron and steel to the value of 7,462,000*l.* were imported. The Commonwealth Government assists private enterprise in developing the resources of the continent by liberal bounties distributed as follows: Pig-iron, made from Australian ore, puddled bar iron made from Australian pig-iron, and steel made from Australian pig-iron, each 12*s.* per ton; galvanised sheet or plate iron or steel, wire netting, wire and iron or steel tubes, 10 per cent. on value.

There is no doubt but that Australia will eventually become a great producer of iron and steel, for the exceeding richness and high quality of the Australian deposits, as compared with those profitably worked in other countries, ensures the expansion of the industry. In a report received by the Australian Interstate Commission, the manager of the Newcastle Steel Works says: "I find that you can assemble at Newcastle the iron ore, coke and limestone for pig-iron production at a lower cost per unit per ton than is possible for the United States Steel Corporation, the largest and cheapest producer in that country." The following figures strikingly demonstrate the richness of Australian iron ore:—

Tons of Ore for 1 Ton of Pig-iron.

United States	2.0
Sweden	2.0
Russia	2.0
Great Britain	2.4
Germany	2.4
France	2.7
Belgium	2.7
Australia (iron knob)	1.5

High-speed, reciprocating and other steam engines are being made in Australia by three or four firms. Not only has the local trade been supplied, but machinery has been constructed for a number of tin-mining plants in the Malay States. In a report presented to Parliament in 1916, the Commonwealth Interstate Commission laid stress on the fact that steam engines, marine engines and boilers were being efficiently made in the country, and recommended an increase in the tariff rates in order to protect local manufacturers. The increases suggested for the consideration of Parliament (which directed the Commission to investigate tariff matters) are marine engines under 1,500 h.p. and boilers under 1,000 h.p., from 20 per cent. (with no preference to British goods) to 40 per cent. general and 30 per cent. preference; marine engines over 1,500 h.p. and boilers over 1,000 h.p., 10 per cent. general and free preferential. High-speed reciprocating and other steam engines, from 5 per cent. general and free preferential to 40 per cent. general and 30 per cent. preferential. These rates are suggested with the object of giving direct encouragement to the manufacture of high-class machinery in Australia. Machinery, exclusive of electrical or agricultural, was imported into Australia in 1913 to the value of 3,367,700*l.*

High freights and limited shipping space will prevail for some time after the war, and will place considerable restrictions upon the export of machinery to the Commonwealth.

DANISH SHIPBUILDING.—At the general meeting of the Burmeister and Wain Shipbuilding Company, some detailed information was given about the impending large expansion of the concern. Several years before the war, extensions had been under contemplation on account of the success of motor vessels, and an additional area had been secured. Thereby the yard's capacity for building new vessels can be greatly increased, and the firm will be able to build vessels of 600 ft. length. Last year a large boiler shop was erected, the quay accommodation was much improved, and the depth of water increased, so that large vessels can now come alongside. The engine and motor shop is to be extended, so that the company not only will be able to build motors for all their own vessels, but they will also be able to engine other large ships. All this had been done with a view to an increasing business; the firm's engineers had designed machine tools, manufactured at the company's own shops, whilst other new special machines had been purchased, so that the firm, backed up by its experience and good reputation, should be able to meet all competition. The cost of the new works had been defrayed from funds in hand. As regards the Diesel motors, licences for making these had during the year been placed in several countries; these royalties will bring in a satisfactory royalty income. In the year 1917 great difficulties had supervened in the matter of obtaining raw material and as all supplies of raw material, machines, metals of all kinds, &c., from England and America ceased, the firm had to rely upon Germany. This had greatly hampered the work on new vessels; it was only possible to proceed with such work for which steel was stored in the Free Harbour. Only one vessel was delivered during 1917, the motor vessel Valparaiso, to the Nordstjörnan Company, Stockholm. This was 3,762 gross tons and 2,600 i.h.p. There were repaired 180 Danish and 56 foreign vessels, against 216 Danish and 92 foreign the previous year. The sale of the stationary Diesel motors had been satisfactory, and the steel works and smithy had proved of the greatest value. Working expenses had risen tremendously especially owing to the high prices for coal and oil.

ON GRAIN SIZE.*

By G. H. GULLIVER, D.Sc., F.R.S.E.

IN studying the features of a piece of metal or alloy it is of interest to measure the dimensions of the crystalline units, and to seek relations between the physical properties of the mass and the size of the crystals. Sometimes those dimensions are so variable that any effect of their magnitude is obscured by other factors, but there is a fairly widespread belief that, under favourable conditions, the crystal grains approximate to a uniform size and uniform compact shape throughout the piece, and the term "grain size" is in common use. It is unfortunate that there is frequently insufficient evidence that the employment of this term is legitimate.

The term "grain size" is usually applied to the average area of section of a crystal grain, found by dividing the number of sections visible on a given micrographic area into the magnitude of the area; and the use of the term is often considered justified if the examination of several micrographs, taken at different positions and directions in the piece, yield nearly the same numerical value of the mean granular area. A cursory examination of a micrograph shows that there is a large variation in the size of the grain sections—too large, in fact, for the satisfactory employment of a mean if the sections were disconnected quantities. Actually, of course, the areas of the various grain sections do not vary independently; the real significance of "grain size" is mean granular volume, and the term implies that the volume of each crystal grain approximates with sufficient nearness to the average volume to allow the term to have a real meaning.

The size of a grain is measured as a two-dimensional quantity, because the determination of a granular area is much easier than that of a granular volume, and, for the same amount of trouble, it gives a more reliable indication of size than a linear measurement would do. If all the grains in a mass are of nearly the same size and shape, it does not much matter, apart from the question of convenience, whether the size is measured as a one, two, or three-dimensional quantity, since the three quantities bear nearly fixed relations each to the others; but variation in the size of the grains, in their shape, or in their manner of distribution, disturbs those dimensional relations.

Attention is confined here to the relation between the mean volume of a grain and its mean area of section, when the material shows only one kind of structural constituent. If the grains are distributed in random manner throughout the mass, their polygonal sections on the prepared surface are of variable magnitude. But with grains of approximate equal volume, and approximately the same compact shape, a micrograph of given area, large compared with the maximum area of section of a grain, shows a nearly constant number of grain sections, from whatever part of the mass it is obtained. Reasonable objection may be made that the wording of the last sentence is too vague, and that some more definite language should be used. Accordingly, "approximately equal volume" may be interpreted as indicating a permissible variation in volume of, say, $\pm$ 10 per cent.; "approximately the same compact shape" may be regarded as meaning a polyhedron of, say, 12 $\pm$ 2 faces, with a permissible variation of $\pm$ 5 per cent. among its corresponding diameters; and "large" may be taken to mean that the measured area of the micrograph includes not less than 200 grain sections. These figures are chosen arbitrarily, but it is believed reasonably. Before the manner of distribution can be determined, it is necessary to discover a few specimens in which the grains are of reasonably uniform size; so far, no such specimens have been found, and the effect of distribution must be left out of account for the present.

The approximate relation of the two-dimensional grain size to the mean granular volume can be determined in the following manner.

Suppose the mass of material to be a cylinder of any form of section. Let the height of the cylinder be H, and let its cross-sectional area be A.

Let N be the total number of grains in the cylinder. Let the mean diameter of a particular grain be d. Then the mean volume of that grain is $k\,d^3$, where k is a numerical fraction which depends upon the shape of the grain.

Let $\bar{d}$ be the average value of d for the N grains. Then, if the variation among the grains is limited as stated above, the average granular volume is equal to $k\,(\bar{d})^3$, with an error of not more than $\pm$ 4 per cent.

Let a number of parallel slices of the cylinder be taken at small distances δ apart, and let n be the mean number of grains cut by one face of each slice. Then the total number of grain sections made by one face of all the slices is

$$n \,.\, (\text{number of slices}) = n\,\frac{H}{\delta}.$$

The total number of grain sections is also

$$N \,.\, (\text{number of sections of each grain}) = N \cdot \frac{\bar{d}}{\delta}.$$

Therefore

$$n \,.\, \frac{H}{\delta} = N \,.\, \frac{\bar{d}}{\delta}.$$

And

$$n = N \,.\, \frac{\bar{d}}{H} = \frac{A\,H}{k\,(\bar{d})^3} \cdot \frac{\bar{d}}{H} = \frac{A}{k\,(\bar{d})^2}.$$

Or the mean area of a grain section, within the limits of error already stated, is

$$\frac{A}{n} = k\,(\bar{d})^2.$$

The diameter which is to be regarded as the mean diameter $\bar{d}$ of a grain is that which will yield an average number of sections of the grain; it may be taken as the arithmetic mean of the diameters of two spheres approximating, as closely as the shape of the polyhedron will allow, to an inscribed and a circumscribed sphere.

The value of k for a polyhedron of compact form, having an average of 12 faces, is somewhat less than $\frac{1}{2}$, say, 0.48 $\pm$ 5 per cent. Thus the approximate area of a grain section is

$$\frac{A}{n} = \frac{(\bar{d})^2}{2}.$$

And the mean volume of a grain is, in round figures,

$$k\,(\bar{d})^3 = \frac{3}{2}\left(\frac{A}{n}\right)^{\frac{3}{2}}$$

where $\frac{A}{n}$ is the area usually denoted grain size.

From the above result may be obtained another which promises to be of greater interest, though the degree of numerical accuracy is less than before. It has been stated that, if the grains are approximately equal and equiaxed, a section of the mass taken at random yields a nearly constant grain size. But the converse is not necessarily true, and a constant two-dimensional grain size might only indicate a recurrent form of distribution as, for instance, one in which a large grain is surrounded by several smaller grains. A ready means of detecting a gross departure from uniformity is to measure the areas of the grains on a suitable micrograph, and compare the maximum with the mean.

The area of the largest section which can be cut from a grain is $c\,d^2$, where c is a numerical fraction approximating to 0.8 when the section is a polygon of compact shape with six to 10 sides, and d has the meaning already assigned to it. Taking the limits of variation in the grains as before, and ignoring for the moment any variation in the coefficient c, the extreme limits of variation of the maximum area are about $\pm$ 12 per cent.

The value of the ratio of maximum to mean grain area as actually measured, will vary on account of

(1) Variation in the size of the grains.
(2) Variation in the shape of the grains.
(3) Improbability of any one grain being cut exactly along a plane of maximum area.

The ratio will be increased on account of (1), and decreased on account of (3). With regard to (2), the value of c changes, but not greatly, with the number of sides of the polygon. The maximum variation of the ratio is in the neighbourhood of 20 per cent., and the value of the ratio is

$$\frac{\text{maximum grain area}}{\text{mean grain area}} = \frac{0.8}{0.48} = 1.7 \pm 20 \text{ per cent.}$$

or, roughly, from 1$\frac{1}{2}$ to 2. An alteration of the arbitrarily chosen limits of variation among the grains will, of course alter the limits of accuracy of the numerical result.

The above ratio, though its possible values lie between somewhat wide limits, may be usefully employed as a criterion of uniformity of the grains; that is to say, if in a section of a metal, with approximately equiaxed grains, the ratio of the largest grain area to the mean grain area is sensibly greater than 2, the grains cannot be described as of nearly uniform size. Geometrical distributions of grains are possible from which special sections would give a value of the criterion lying anywhere between 1 and 2, or even considerably above 2, but such distributions are not regarded here. A criterion less than about 1$\frac{1}{2}$ would indicate a special kind of distribution.

The obvious sequel to the preceding paragraphs is an extensive series of actual measurements. At present little time is available for matters of interest not directly connected with the war, and the specimens measured have been neither numerous nor entirely suitable. The value of the ratio of maximum to mean grain area in these was found to lie between 3$\frac{1}{2}$ and 5, the higher values being obtained after longer periods of annealing; in other words, the grain size was far from uniform, and annealing increased the degree of non-uniformity. There is a temptation to say more about the change in the size of the grains during annealing, but the matter will not be carried further at present, or the length of a "note" will be too much exceeded.

The above arguments may be extended, with slight modification, to certain alloys which show more than one structural constituent. In a case where the crystal grains, although of approximately uniform shape and volume, are not of compact form, the use of the term "grain size" is not convenient without proper reference to the shape of the grains; examples are the elongated prisms of a drawn bar and the pyramids of a chilled casting. The dimensional relations in such a case are obviously different from those given here, and they are not the same for all sections of the mass.

* Note read before the Institute of Metals on Thursday, March 14, 1918.

PRUSSIAN RAILWAY LOAN.—A Bill has been introduced into the chamber for a new railway loan, according to which 726,352,000 marks are required for the State railways, for new rolling-stock, &c. Some 650,000,000 marks are to be applied to an increase of the capacity of the State railway system. The requirements comprise 1,850 locomotives, 1,800 passenger carriages and 35,906 goods wagons, &c. Of this total, 550 locomotives, 750 passenger carriages and 6,300 goods wagons, and a ferry, are to replace rolling-stock which has been worn out during the war.

CATALOGUES.

Books.—A copy of a catalogue of books comes from Mr. William Downing, bookseller, 5, Temple row, Birmingham, containing many volumes of general interest and a few of strictly technical interest, all priced

Locomotive Engines.—The Santa-Fe type, a ten-coupled, engine for fast passenger service, is described in a booklet issued by the Baldwin Locomotive Works Philadelphia, U.S.A. Full measurements are given for several engines with a reasoned statement of the special features introduced from time to time. Like many of the Baldwin Works publications the booklet approaches the value of a treatise, while being useful as a catalogue.

Laboratory Crucibles.—A crucible with capacity to melt 10 lb. of copper is shown in a catalogue which comes from the Davis Furnace Company, Luton. The casing is of wrought iron on a cast-iron base, heavily lined with firebrick, fitted with hinged brick cover and $\frac{1}{2}$-in. air and gas pipes. An air pressure of 3 lb. is required. The total weight is over 1 cwt. It should be found useful for any small work, as it is very substantially made and conveniently fitted. This firm reports that the demand for oven furnaces now greatly exceeds the demand for metal-melting furnaces.

Small Electric Tools.—A series of tools, including external and internal grinders, drillers and buffing tools, is shown in a catalogue from the Sun Electrical Company, Limited, 120, Charing Cross-road, London, W.C. 2. The external grinder is adapted to fix on the slide rest of a lathe and the internal in a tool box by a tool shank. The drillers are hand tools and there are three makes for particular positions of use. The buffing machine is held with two hands and carries a buff or emery wheel up to 2 in. diameter; the speed is 8,000 r.p.m., so that it could be passed over any surface for polishing or light grinding. The drillers are sufficient up to $\frac{1}{16}$ in. to $\frac{3}{4}$ in. All the motors will run on either alternating current or direct current, and the tools are very neatly and strongly made.

Varnishes and Enamels.—A catalogue of these manufactures from Messrs. Jenson and Nicholson, Limited, Stratford, London, E., is divided into eight sections giving full technical information to meet all the requirements of electrical work. Black and golden brown insulating varnishes, finishing varnish for windings, core-plate varnish, acid proof enamel and paint, mica varnish, machine-finishing enamels and heat radiating enamels are each made in several varieties for special purposes, and the firm is willing to give electrical engineers special information about such matters. This small, handy catalogue contains a great deal of detailed information stated with exceptional conciseness and lucidity. Specific gravity and temperature tables are also given.

Vibration and Noise.—Industry develops by never ending subdivision—a division of industry recalling Adam Smith's description of division of manual labour on a grandly enlarged scale. The British Anti Vibration and Noise Company, Limited, 105, St. Vincent street, Glasgow, send a catalogue which indicates that a special technical staff makes a study of the vibration and noise created by machinery in action, and designs various pads, plates, and foundations for isolating machines, so that the tremours and noises are reduced. The vibrations transmitted only to the air in a room, and those transmitted through the structure of the building, are discussed in an informative way, and examples of the isolating means are shown applied to electric motors, rotary converters, transformers, and to fans, shafting, printing machines, dough kneading machines, air compressors, &c. Beams and girders are isolated at their ends and special wall material is described. The catalogue is well worth attention.

Electric Current Converters.—The growing demand for rotary converters gives special interest to a catalogue of these machines issued by Messrs. Vickers, Limited, Sheffield. Local authorities having comparatively small generating plants and an increasing demand for current may, in many places, buy a bulk supply from a large district power company instead of increasing their own plant. The tendency is to prefer taking the bulk supply which involves much less capital expenditure and allows for easy expansion to meet the local requirements. The installing of new engines, boilers and generators and, perhaps, of extensions of power-house, is avoided. As against these advantages it is necessary to instal transformers and means of conversion, because the bulk supply is generally three-phase high-tension, while the local requirement for light and power is for direct current. The change, apart from transforming to lower voltage, may be effected by motor generators; that is, direct-current generators driven by motors which take their power from the bulk supply. The simpler method, now thoroughly adequate, is the rotary converter, which directly converts one form of current to the other. It is a single machine, running on two bearings, as against three or more on the motor generator; the capital and upkeep costs are much less; the floor space required is considerably less and the overall efficiency is 6 per cent. to 8 per cent. better. The revolving armature of the rotary converter has slip rings at one end for connection to the alternating current intake (after suitable reduction in the transformer) and at the other end a commutator from which the direct-current output is delivered. Additional machines can be laid down as required. The catalogue, which is altogether well worth reading, gives full particulars of variations in construction and equipment to suit local requirements; also diagrams, illustrations, and fully descriptive specification.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACT OF 1907.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, &c., of the Communicators are given in italics.

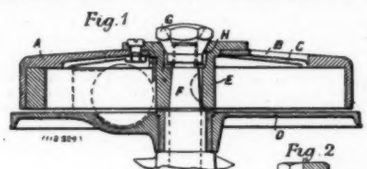
Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 6d.

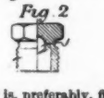
The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any grounds mentioned in the Act.

ELECTRICAL APPARATUS.

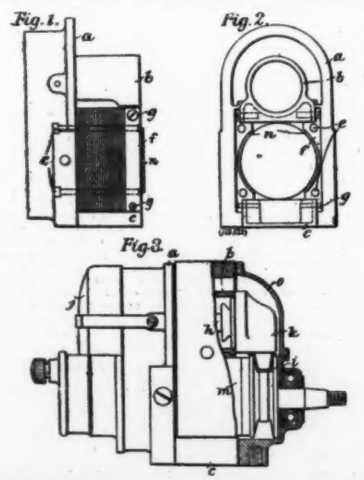
112,529. The Villiers Engineering Company, Limited, Blakenhall, Wolverhampton, G. Funck, Coventry, and F. H. Farrer, Penn. Flywheel Magneto Devices. (3 *Figs.*) January 31, 1917.—This invention is for improvements in or relating to flywheel magneto devices for internal-combustion engines. According to this invention, the flywheel is formed as a spoked wheel and has a conical bore in the hub with an internal screw thread at the outer end. The outer end of the bore can be enlarged for screw-threading and provided with a conical mouth, the flywheel being fixed in place by a nut which screws on to the engine shaft, and has a conical shoulder to engage the mouth of the enlarged end of the said bore. The purpose of this arrangement is to hold the flywheel securely in place but allow of its being readily withdrawn by the insertion into the enlarged end of the bore, after the coned nut has been removed, of a withdrawal plug comprising a single hollow nut, which is recessed at its end to receive the end of the engine shaft and screw threaded on its exterior to engage the thread in the enlarged end of the bore of the boss.





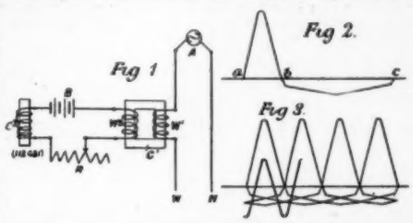
The wall of the recess in the end of the plug is, preferably, fitted with a ball to reduce friction, and the recess is not deep enough to allow the plug to be screwed home without its withdrawing the wheel from the shaft, and thus the wheel is easily loosened and then can be removed by hand. A is a hollow flywheel with spokes B strengthened with ribs C. D is the back plate carrying the contact breaker, induction coil, condensers, &c. E is the flywheel hub formed with a conical bore to fit the conical end of the shaft F, and held thereon by a coned nut G. The outer end of the bore of the hub is enlarged and provided with a screw thread H adapted to receive a withdrawal plug I (Fig. 2) when it is desired to remove the flywheel from the shaft. When the withdrawal plug I is screwed into the hub, the end of the shaft engages the ball J in the plug before the latter beds against the bottom of the enlarged portion of the bore, and thereby the flywheel can be forced off the conical portion of the shaft. (*Sealed.*)

112,532. E. A. Watson, and The M-L Magneto Syndicate, Limited, West Orchard, Coventry. Magnetos. (3 *Figs.*) February 1, 1917.—This invention relates to ignition magnetos for internal combustion engines. One of the end covers *a* has provided on it, and preferably integrally with it, parallel extensions *b* and *c*, between which pole piece laminations *d* can be slipped. Each of the two groups of laminations is held in position by longitudinal rivets *e* inserted through the end cover, the



laminations, and also an end plate *f*. The latter is made thick enough to admit of one or more transverse screws *g*, which pass through the end plates only, into the extensions and hold the pole-pieces against movement in a direction at right angles to the axis of the armature. The extension *c* serves as a cover for one side of the armature. The extension *b* forms part of a tunnel which encloses and carries the distributor spindle A. To provide for the total enclosing of the high-tension conductor between the slip ring *i* and the distributor arm (not shown, but enclosed in the front part *j* of the machine), the pick-up *k* is shaped to serve also as a cover for one end of the aforesaid tunnel, this being held in position by a spring blade in the adjacent outer end cover of the machine. To permit of a slip ring construction in which the flanges are larger in diameter than the armature *m*, the end plates *f* of the pole pieces are shaped to form a spigot *n* and the end cover *o* which encloses the slip ring is recessed to fit over this spigot. (*Sealed.*)

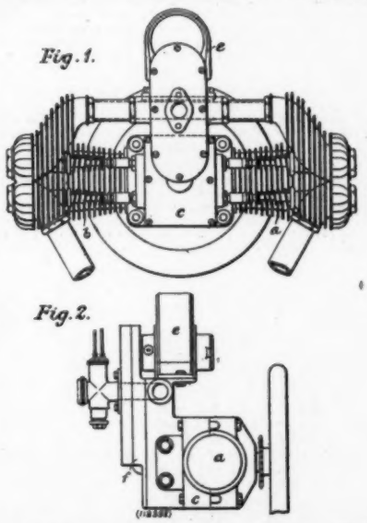
112,481. Marconi's Wireless Telegraph Company, Limited, and I. Shoenberg, London. Multiplying the frequency of Electric Currents. (3 *Figs.*) December 5, 1916.—This invention relates to a method for multiplying the frequency of electric currents. The invention is based on the following principle: If one of the mains from a source of alternating current include a winding upon an iron core in which are no air gaps, or at most very small ones, and which has a second winding in circuit with a source of direct current, and a choking coil with an open core, the curves for the current and voltage in the main will possess the peculiarity that the amplitude on one side is much larger than that on the other, while that portion of the period which corresponds to the larger amplitude is smaller than the portion corresponding to the smaller amplitude, the ratio of the one portion to the other being a function of the ampere turns of the two windings. In Fig. 1, A is a source of



alternating current, C1 is an iron core with no gaps, or with very small ones, and on this core are placed two windings, the one W1 is inserted in one of the mains from A, while the other W2 is connected to a source B of direct current through an adjustable resistance R and a choking coil C2; having an open core so that the core C1 can be saturated. The curves for the current or voltage between the points M, N, of the main will be of the form shown in Fig. 2. In this figure *a c*, corresponds to a full period, the amplitude on one side is much larger than on the other, and the part *a b*, is much smaller than half a period. A similar arrangement is introduced into each of the phases of a supply of *n* phases, and if the currents in the several phases are combined, there is obtained a current of a frequency *n* times that of the fundamental, as shown in Fig. 3, for the case of a four-phase supply. It will be observed that the phases are directly added without the employment of transformers. (*Accepted January 23, 1918.*)

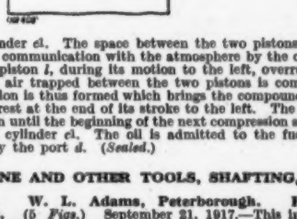
GAS ENGINES, PRODUCERS, HOLDERS, &c.

112,392. W. Comery, Mapperley Park, Nottingham, and The Raleigh Cycle Company, Limited, Lenton, Nottingham. Internal Combustion Engines. (3 *Figs.*) July 24, 1917.—This invention relates to twin-opposed cylinder internal-combustion engines, and refers more particularly to such engines adapted for use on motor cycles and the like. According to the invention, the engine cylinders *a*, *b* are secured at opposite



ends of a common crank-case *c* after the usual manner. The timing gear case *f*, which usually contains the driving mechanism for the camshafts, and, in some cases, the driving mechanism for the magneto, is arranged on one of the side faces of the crank-case *c*, a bracket being provided to carry the magneto *e*, which overhangs said case, the arrangement being such that a free air space leading to the back cylinder is provided between the latter and the magneto. (*Sealed.*)

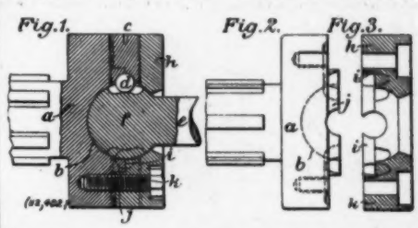
112,409. W. H. Watkinson, Liverpool. Internal-Combustion Engines. (1 *Fig.*) October 6, 1916.—The invention relates to that type of internal-combustion engine in which liquid fuel is injected into the working cylinder by means of air at a higher pressure than that within the cylinder. During the compression of the main air in the cylinder *c*1 some of this air is forced through pipe *i* past the automatic valve *j* into the fuel valve chamber *c*, through which it flows into the cylinder of the small piston *m*. This air pushes the piston *m* to the end of its stroke remote from the fuel valve chamber, and in doing so it compresses the air behind the larger piston *l*; this air thus acting as a cushion for the piston. Slightly before the instant at which the fuel valve *b* is opened, the mechanically-operated valve *k* is opened and compressed air from cylinder *c*1 flows through pipe *n* into the cylinder containing the piston *l*. The pressure of the air acting on the right-hand side of piston *l* is then approximately equal to the pressure of the air acting on the left-hand side of piston *m*, but as the area of piston *l* is greater than the area of piston *m*, the compound piston is forced to the left and the pressure of the air in the needle-valve chamber *c* is raised sufficiently to enable it to effect the spraying of the oil into the



engine cylinder *c*1. The space between the two pistons of this pump is in communication with the atmosphere by the orifice *o*. When the piston *l*, during its motion to the left, overruns this orifice, the air trapped between the two pistons is compressed and a cushion is thus formed which brings the compound piston quietly to rest at the end of its stroke to the left. The valve *k* is kept open until the beginning of the next compression stroke in the engine cylinder *c*1. The oil is admitted to the fuel valve chamber by the port *d*. (*Sealed.*)

MACHINE AND OTHER TOOLS, SHAFTING, &c.

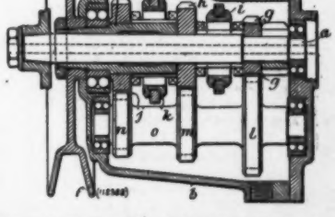
112,402. W. L. Adams, Peterborough. Flexible Couplings. (5 *Figs.*) September 21, 1917.—This invention relates to details of construction of flexible couplings of the type consisting of two members, one member having a spherical cavity formed in two parts secured together by screws and holes leading to the cavity which are closed by screw plugs, and the other member having a sphere fitting into the spherical cavity, the coupling between the two members being formed by balls contained in grooves in the sphere and in partly spherical cavities on the inner ends of the plugs. In one member *a* of the coupling is a spherical cavity *b* into which lead holes, preferably six in



number, closed by screw plugs *c*, and at the inner ends of the plugs *c* are partly spherical cavities to receive balls *d*. On the end of the other member *e* is a sphere *f*, having grooves into which the balls *d* enter when the members of the coupling are assembled together. The two members *a* and *e* are held together by means of a flange *h*, in which is a groove *i*, into which enter projections *j* on the end of the member *a*. The flange and the member *a* are secured together by screws *k*. The movement of one member is communicated to the other through the balls *d*, which are easily adjusted by means of the screw plugs *c*. (*Sealed.*)

MOTOR ROAD VEHICLES.

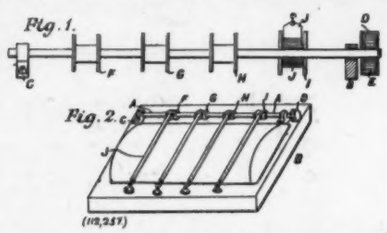
112,388. W. H. Raven, Nottingham and The Raleigh Cycle Company, Limited, Lenton, Nottingham. Change-Speed Gearing. (1 *Fig.*) July 17, 1917.—This invention relates to change-speed gears of the type in which gear wheels on the main or countershaft are adapted to mesh with gear wheels on a lay shaft, the driven shaft or member being coaxial with the main shaft and a pinion, loose on the main shaft, being clutchable alternatively to the driving and driven members. According to the invention, a shaft *a* driven from the motive power is journalled in a suitable casing, a sleeve *d* being rotatably mounted on one end of the same, to which is connected the driving pulley *f*.



Parallel to and adjacent to the first-mentioned shaft *a* is a second or lay shaft *o*, also rotatably mounted in the casing *b*, and provided with three fixed pinions *n*, *m*, *l* of graduated size. The latter mesh with three further pinions *g*, *h*, *j*, two of which *g*, *h*, are rotatably mounted on the shaft *a*, while one *j* is mounted on the sleeve *d*. Slidably mounted on the latter is a dog-clutch *k* adapted to clutch either the pinion *j* or the pinion *h* to the sleeve *d*, a second dog-clutch *i* being slidably mounted on the shaft *a* and adapted to clutch either of the pinions *g*, *h*, to the shaft *a*, the arrangement being such that by the manipulation of the before-mentioned clutches *k*, *i*, four separate speeds can be obtained. (*Sealed.*)

112,287. R. Blakoe, London. Gas Bags or Reservoirs. (5 *Figs.*) October 25, 1917.—This invention relates to improved means of controlling and retaining gas bags or reservoirs, the

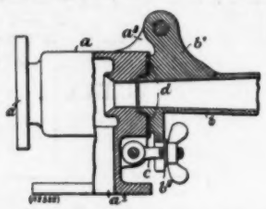
same being used to act as a compressor. In carrying the invention into practice, a rail A is fixed on one side of the exterior roof or top of the car by means of brackets B, C. The rail has a drum or circular box D, in which is contained a spring E capable of being wound or coiled up to the requisite tension or compression. Along the rail A is mounted, at proper distances apart, a number of bobbins or pulleys F, G, H, I, moving rigidly with the rail. Suitable strands J composed of canvas or other non-elastic or elastic material, are attached to the bobbins or



pulleys. These strands are coiled round the bobbins or flanged pulleys due to the coiling up of the spring E, and when the strands are drawn out with their ends still attached to the bobbins they are made to envelop or cover a gas bag or gas reservoir containing the usual volume or capacity of gas; a compression is put thereupon in order to press out the gas or fluid. Any suitable number of bobbins or flanged pulleys may be employed. The operation of unwinding is utilised to coil up the spring. (*Accepted January 9, 1918.*)

PUMPS.

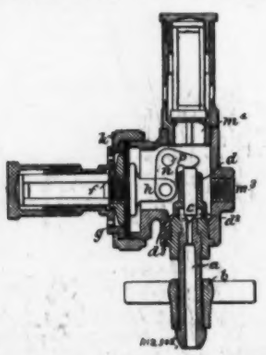
112,522. T. Taylor, Woodley, Stockport. Ejectors. (1 *Fig.*) January 26, 1917.—This invention relates to ejectors for raising and circulating fluids. According to this invention, the delivery nozzle is hinged or pivoted to the body and normally secured by one or more fastenings on the undoing or removal of which the nozzle can be turned aside on its hinge or pivot to allow of access to the interior of the body. *a* is the body of the ejector, *a*1 the inlet thereto for the steam for inducing a suction through the suction inlet *a*2, to which the suction pipe (not shown) is connected, and *b* the delivery nozzle which, instead of being screwed into the body *a*, as hitherto, is hinged thereto. Preferably, the nozzle *b* is formed with a lug *b*1 pivoted to and



between a pair of complementary lugs *a*3 on the body *a*. Opposite the lugs *a*3 there is also pivoted on the body *a* a swing bolt *c* fitted with a wing-nut and adapted to co-act in the known way with lugs *b*3 on the nozzle *b* to clamp same. On releasing the nut and swinging the bolt *c* clear, the nozzle *b* can be swung on its pivot to permit of access to the interior of the body *a* for the purpose of removing any obstruction. The nozzle *b* is formed with a spigot portion which enters a corresponding recess in the body *a* and a washer *d* is provided in a recess in the body for the purpose of making a tight joint between the body and the nozzle. (*Sealed.*)

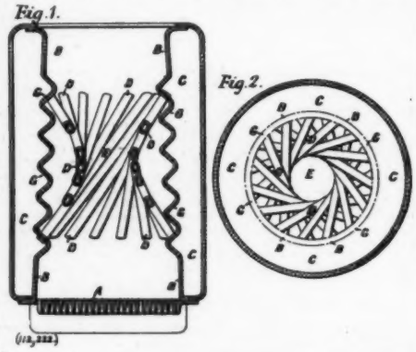
STEAM ENGINES, BOILERS, EVAPORATORS, &c.

112,548. David Auld and Sons, Limited, J. Auld, and J. Graham, Glasgow. Fluid Pressure Reducing Valves. (1 *Fig.*) March 21, 1917.—According to the improvements of this invention, the valve seat is screwed into the end of a housing guide member which is screwed into the valve body. The valve slides through the other end of this guide housing, which is of sufficient length to form a guide for the valve. Immediately above the valve seat a chamber annularly surrounding the valve and provided with outlet holes is formed in the housing member. The end of the valve spindle is in free engagement with the one limb of a bell-crank lever pivoted to the valve body, while the



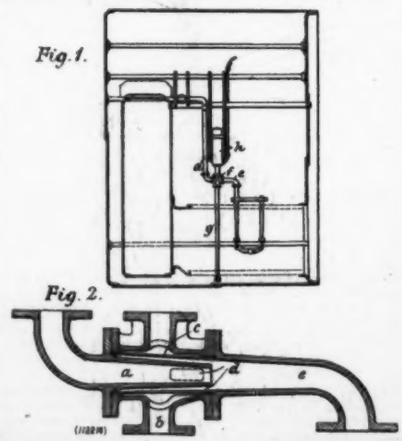
other limb of the bell-crank lever is pivotally connected to an extension of the spindle carrying the loaded piston and diaphragm. The inlet seat *a* is fixed to the high-pressure system by means of coupling *b*. The valve *c* is guided and maintained concentric to the inlet seat *a* by means of the concentric guide *d*. Guide *d* has an annular space *d*2 directly above the inlet seat *a*, and small holes *d*3 connect this space to the space inside valve body and hence to the outlet side at *m*3. The piston *f* is exposed on the one side to the outlet pressure and on the other to the atmospheric pressure. It is maintained pressure-tight on the outlet side by means of the flexible diaphragm *g*, which is fixed centrally between piston *f* and washer *h* screwed into the piston, and circumferentially by the screwed ring *k*. Piston *f* controls the valve *c* by means of a cranked lever *n*, which moves about a fulcrum pin *p* and is loosely in connection with top of valve *c*. Piston *f* can be loaded to give any required reduced pressure by an adjustable spring. A safety or relief valve of any suitable type may be fitted to low-pressure side of reducing-valve body at *m*4. The mode of action is as follows: High pressure enters at inlet, forces *c* open and expands into annular space *d*2, hence per ports *d*3 into outlet side. Outlet pressure immediately acts on the piston *f*, which has previously been loaded to a predetermined pressure by means of its spring. Immediately this pressure is reached and slightly passed, the force acting on piston *f* overcomes the force due to the spring and the tendency is to move the piston *f* outwards from valve body. Acting through the crank lever *n* this movement of piston *f* closes or partially closes the valve *c* to prevent outlet or low pressure rising above its predetermined value. If, on the other hand, the outlet pressure tends to fall, the spring overcomes the pressure acting on piston *f* and piston *f* is pressed inwards. This movement of piston *f* in turn opens valve *c* wider in order to prevent the outlet pressure from falling. (*Sealed.*)

112,222. G. Woodvine, Shrewsbury. Vertical Steam Boilers. (4 *Figs.*) April 24, 1917.—The invention relates to vertical steam boilers of the type in which the fire-grate is at the bottom, and there is a central combustion chamber surrounded by an annular water space; and has for its object to provide an improved arrangement of water tubes in the combustion space. According to the invention, the innermost row of tubes—there may be several rows—is grouped about a central circular space in suchwise that each tube touching or closely adjacent to its neighbour where it touches this central circle lies in a plane tangent to the circle. Each tube lies in its plane at an angle to the vertical axis of the boiler and of the circular central space, and thus extends from one side of the circular combustion chamber to the other, taking a landing therein towards the bottom at one side and towards the top at the other side of the combustion chamber. A is a fire-grate



and B a central combustion chamber surrounded by an annular water space C. According to the invention, water tubes D in the combustion chamber B are grouped about a central circular space E, in suchwise that each tube, touching or closely adjacent to its neighbour, where it touches this central space, lies in a plane tangent to the circle. Each tube D also lies in its plane at an angle to the vertical axis of the boiler and of the central circular space E, and thus extends from one side of the combustion chamber B to the other. The inner wall G of the water space C surrounding the combustion chamber B is so corrugated that the parts of the uppermost and lowermost corrugations which are opposite the ends of the tubes lie substantially at right angles to the ends of the tubes, and form landings for them, the bottom of each tube taking a landing thereon towards one side and the top of each tube toward the other side of the combustion chamber B. (*Sealed.*)

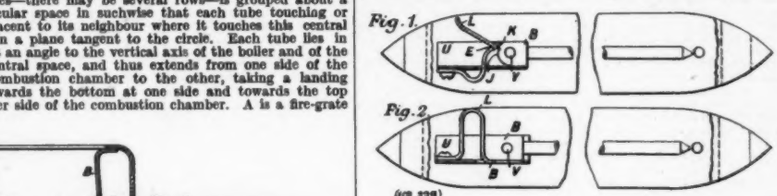
112,214. J. Brundrit, Liverpool. Feed-Water Heating and Boiler Circulating Appliances. (3 *Figs.*) April 3, 1917.—This invention relates to feed-water heating and boiler circulating appliances of the type in which the feed water is caused to form the motive fluid in an ejector, the suction pipe of which extends to the lower or cool-water space of a Scotch or other internal flue type of boiler, whilst the delivery pipe causes a



circulation of the water in the boiler for temperature equalisation purposes. In accordance with the invention, the ejector nozzle *a* through which the boiler feed-water issues, is contained or extended well beyond the suction inlet *b* to the ejector, and a sleeve-like member *c* is provided around the nozzle *a* and at a short distance therefrom, having apertures *d* therein through which the suction water issues on its way to the propelling jet from *a*, the sleeve *c* serving to give correct alignment and concentricity of the nozzle with the ejector delivery portion *e* so as to ensure efficient and reliable working. Preferably, the sleeve is positioned between a recess in the inner end face of said delivery part *e* and the flange end of the nozzle *a*. The inner surface of the delivery portion *e* is continuous with the inner surface of the sleeve *c*, so that correct alignment and concentricity of the parts are ensured. The ejector *f* may be fitted in the suction pipe *g* of an automatic pulsating type boiler circulator *h*, when it serves to increase the rate of circulation. (*Sealed.*)

TEXTILE MACHINERY.

112,229. A. Cass, Swinton, Manchester. Loom Shuttles. (2 *Figs.*) November 13, 1916.—This invention relates to the tongues of loom shuttles. The base B of the tongue hinges on a pivot V either carried directly in the wall of the shuttle or preferably in a trough-shaped metal piece U fitted into the body of the shuttle. In the drawing, the wall of this piece is removed and the bottom of the trough is shown in section. When in its operative position one face of the base B lies against the bottom of the trough U, or against other convenient stop, and is locked in this position by a stout spring catch L secured to the trough U, and having a tapered projection E which is pressed under the corresponding incline K of the notch J on the base B. The notch J and the projection E are correspondingly tapered, the notch being made deep enough to permit the projection to enter further and further as wear parts takes place. Any attempt to raise the tongue causes the



incline K to press normally on the surface E and, as this cannot give way in this direction the locking is rigid. Any slight wear that still takes place either in the pivot V or the surfaces K and E is automatically taken up by the incline E springing further into the notch J. The projection E can be drawn out of the notch J by pressure of the thumb on the part L, when it is required to raise the tongue, so that there is no danger of bending it, all the strain and friction being taken off the pivot and base of the tongue. In Fig. 2 an alternative arrangement is shown. The lip R of the spring L passes under the base B and, pressing upwards on the left of the pivot V, forces the right end of the base B firmly on the bottom of the trough U or other stop. Pressure of the thumb on the part L removes the spring pressure, and the tongue can be raised without risk of bending it and without friction and consequent wear of the pivot V or base B. (*Sealed.*)

MISCELLANEOUS.

112,247. F. W. Mellowes, and H. Foulston, Sheffield. Glazing. (1 *Fig.*) August 29, 1917.—This invention relates to glazing of that kind in which the glazing bar is of an inverted T form, the head of the T supporting the underside of the glass, whilst strips bent over the shank of the T are provided to press upon the upper side of the glass and secure it in position. According to this invention, a non-metallic, compressed fibrous material, such as felt or paper, rendered weather-proof, is formed into a cover or strip, and is held in position upon the glazing bar by clips secured at intervals along the glazing bar. The glazing bar A is provided with the usual channels B. The glass C is seated

on the resilient water-proof cords D, the cap or cover of compressed, impregnated fibrous material E being secured in place by the metal clips F, which are fixed at suitable intervals by screws G, which pass through the clip material and glazing bar, and are tightened up by means of a nut. Air spaces H are provided to negative the effect of capillary attraction. It will be seen that the cap or cover E, which makes the joint between the bar and the glass, in the outside of a roof, also protects the steel core or bar against rust, and, in addition to this, the steel core or bar is also coated with an anti-corrosive paint. The holding-down clips may be painted in a similar manner. (*Sealed.*)

112,255. W. K. Kaye, Leeds, and London. Door Latches. (4 *Figs.*) October 10, 1917.—This invention relates to improvements in latches for doors and refers to that class of latch mechanism known as "push and pull." A represents the usual "push and pull" lever pivoted at A1 and engaging a nose C on the cam bolt C1, which bolt is spring-pressed by a spring S. The rocking movement of the lever A actuates the bolt cam. Instead, however, of employing the usual "push and pull" handles, there is mounted on one side of the casing B a stud or

actuating-piece P, capable of being pressed into engagement with the lever A to release the bolt cam. On the other side of the casing B a similar piece P1 is mounted at the other side of the pivot A1, to act in a similar manner. These pieces P and P1 project through the casing and or door frame, and are engaged by a suitable nose of a handle H, that when lifted pushes in the piece P or P1, and so actuates the cam bolt and withdraws same from its striking plate before the door is pushed or pulled open. (*Sealed.*)